The Sustainability Transition: Beyond Conventional Development

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1. Context

Civilization is in the midst of a profound global transition. Over two centuries ago, the industrial revolution introduced an age of unprecedented growth in population, consumption and resource use. Since 1950 alone, global population has doubled, energy production has more than tripled and economic output has increased by a factor of five. Inevitably, such rapid growth must butt against the limits of a finite planet. In our era, human claims on environmental resources and disruption of environment support systems have reached a scale that exceeds natural resource renewal and sink assimilation capacities.

Conventional development wisdom generally assumes the expansion of resource intensive consumption and production patterns in industrialized countries and their gradual extension to developing countries. To gauge the scale of increased environmental pressure, if the world's projected mid 21st century population of 10 billion people were to consume resources at the same level per person as in the United States today, world requirements would grow by very roughly a factor of ten. Can such resource intensive lifestyles be maintained and extended to a growing population? Can conventional socio-economic goals and environmental sustainability be simultaneously satisfied? Or would conventional development risk unacceptable deterioration of the resources and ecosystems of the biosphere, and social and economic instability? These questions motivate this study. By addressing them, we hope to contribute to the project of shaping a new development paradigm for the human enterprise in the Twenty-First century.

1.1. The Historic Challenge

The grand question on the historical agenda is whether societies can manage a transition to a new phase of human development which addresses the reasonable social and economic aspirations of the world's people in an equitable manner, and which will begin to reverse environmental decline by improved environmental protection measures and reduced environmental demands. The task is the long journey to environmental and social sustainability.

Such a sweeping transition can be thought of as a set of interlinked sub-transitions in population patterns, technology, values, governance structures and economic organization (Gell-Mann, 1994). Comprehensive transformations in the mode of human development have occurred before in which each of these dimensions has undergone qualitative shifts, for example, the transitions to settled agriculture and then to industrial capitalism.

In the past, new social formations emerged organically, progressing gradually from the opportunities offered by prior socio-economic systems (Harrison, 1992). But today, environmental and social crises arise almost unannounced. If they are able to advance too fast and too far, there is a danger that the present generation will place its

descendants at risk of unmanageable social, economic and environmental disruption. The challenge for the next transition is for humankind to *anticipate* the unfolding crises, to *conceive* an alternative paradigm for development, and to *actualize* the political will for equitable change.

1.2. The Industrial Explosion

The prodigious growth in material consumption, human numbers, industrial production, and claims on land and the whole range of natural resources, is the culmination of the dynamic advance of industrial society towards a world system. From the time of the enclosures through the colonial period to the market expansion of our own era, modern culture has transformed the societies at the center of the revolution, while progressively incorporating (or, if not, marginalizaing) those on the periphery.

A number of factors combined to form a powerful, growth-oriented, modernizing, and dominant world system albeit with sad counterpoints in social disruption, loss of community and environmental degradation. In the first instance, the industrial revolution was catalyzed by an interlinked series of technological innovations which vastly increased labor productivity by substituting machines and inanimate energy for human craft and muscle-power, and sharply improved the capacity to exploit and manipulate raw materials (Landes, 1970).

Technological change both catalyzed and was driven by changes in culture and social organization in a mutually conditioning process of system transformation. The value of possessive individualism became a secular religion sweeping away more traditional and community-oriented norms. In economic theory, but to a much lesser extent in practice, the modern individual was of a new species, a rational, informed and acquisitive agent in the free market. Material wants and needs were met, expanded and transformed in a continuing spiral of production and consumption, while economic efficiency became associated with the private control of investment surplus, the free market and unfettered trade.

At the same time, a number of modern institutions, building on historic antecedents, gradually developed to regularize and reform the nascent capitalist economic system. A modern legal and constitutional framework arose to regulate economic conduct, guarantee contracts and protect, to some extent, social and civil liberties. Meanwhile, oppositional institutions -- labor unions, suffrage movements and minority rights organization -- struggled for, and often won, better working conditions, democratic enfranchisement and social and economic opportunity for marginalized groups.

Parallel and reinforcing attitudes arose in religion (the Reformation), political philosophy and modern science, which became relatively free of received dogma, while embracing values which were compatible with the industriousness and entrepeneurship of the new era. With roots in Judaeo-Christian attitudes toward nature, industrial society

saw nature as a cornucopia, an essentially limitless wellspring of resources, space and services. The scientific revolution, spawned by the new order, in turn, greatly accelerated the process of change through technological applications.

1.3. The Conventional Development Paradigm

Today's world is the product of an accelerating era of industrialization, cultural transformation, economic growth and geopolitical change. In looking toward the future, the natural assumption is often made that the values and dynamics of the industrial system will be progressively played out indefinitely and on a global scale. Though often tacit, this perspective represents a vision of a long-range global future -- a vision that we refer to here as the *conventional development paradigm*[1] -- which is continuous with the socio- economic arrangements, values and lifestyles that evolved during the industrial era.

The constellation of values that underpinned that historic process provides, by extension, the principles that shape the conventional development vision. These include markets, private investment, and competition as the fundamental engine for economic growth and wealth allocation; free trade and unrestricted capital and financial flows to foster globalization of product and labor markets; rapid industrialization and urbanization; possessive individualism as the motive of human agents and the basis for the "good life"; and the nation-state and liberal democracy as the appropriate form of governance in the modern era.

The conventional development scenario envisions the continuous unfolding of these interlinked processes without major social, technological, or natural surprises and disruptions. In this picture, the cluster of factors shaping the world of the 21st century might be thought to include the globalization and deepening of the information revolution; the progressive homogenization of culture on a global scale; the expansion of consumerist and individualist personal values; the convergence of developing country economies, technologies and cultures toward those of industrial countries; the increasing economic dominance of large transnational corporations on an international economic field; and the rise of the borderless economy.

In fact, a number of significant social, environmental and cultural uncertainties could undermine this picture (Kennedy, 1993; Svedin and Aniansson, 1987). Our aim here is to explore the problematic implications of such a conventional development framework in order to weigh better the requirements for a sustainability transition.

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[1] The phrase *business-as-usual* is widely used to refer to a future in which current conditions are projected assuming the gradual evolution of structural patterns and no significant changes in policy. We use the term *conventional development paradigm* to underscore the normative content of such a scenario, which assumes the maintenance of a set of historically contingent values, behaviors and social and political assumptions.

1.4. Sustainability: A New Development Principle

At the 1992 Earth Summit, the nations of the world acknowledged the need to manage the transition by adopting a new model to guide global, national and local development. *Sustainable development* would seek to provide for the people of today while protecting the quality of natural resources and ecosystems for future generations. This bold idea, while clear in spirit, remains to be realized as a practical basis for action. This awaits the formulation of concrete sustainability principles, targets and plans. Given the breadth of this new concept, it is not surprising that the term sustainable development has been used in a variety of ways (Lele, 1991).

Furthermore, the concept inherently is normative. Indeed, the root concept of sustainability, the call to protect ecological systems for future generations, is itself an ethical appeal. The notion of sustainability is both rich and labile, and the use of the term reflects the values of those using it -- a banker can speak of sustainable economic growth, an environmentalist can stress the idea of the intrinsic value of nature, or a social reformer can insist that sustainability embrace the goals of social justice and poverty eradication.

To develop the sustainability concept further, it is useful to introduce the notion of the *socio-ecological system*. As illustrated in Figure 1, the socio-ecological system is comprised of economic, social and ecological subsystems and their interactions (Shaw et. al., 1991; Gallopin, 1994). The economic system includes capital, production and labor; the social subsystem includes consumption patterns, demographics and culture; and the ecological subsystem includes ecosystems, natural resources and biophysical processes. Socio-ecological systems defined at local, national, regional and global scales interact through cultural influence, environmental impacts, transnational corporate and financial institutions, trade, global governance, and so on (see Figure 2).

Figure 1 The Socio-Ecological System

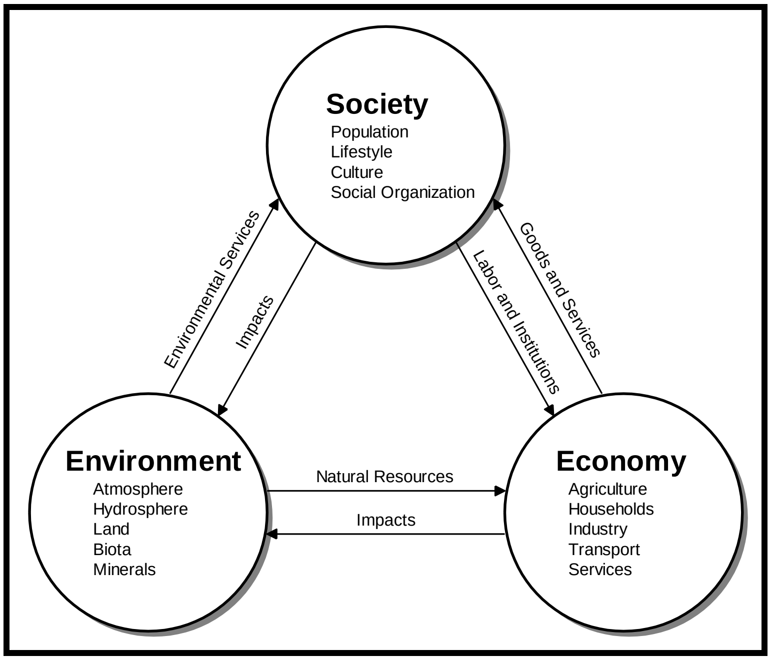
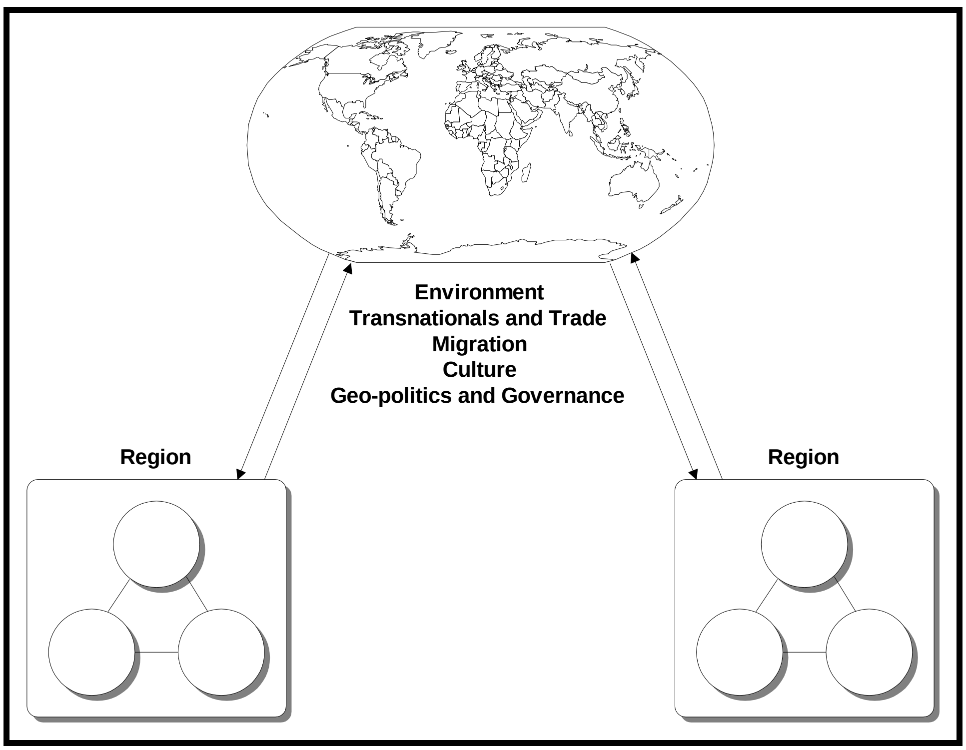


Figure 2 Global Linkages



In the broadest sense, sustainability refers to the capacity for socio-ecological systems to persist unimpaired into the future. This by no means implies stasis -- an impossibility in complex and dynamic systems -- but rather the capacity to adapt and develop. A sustainable system is *resilient* in the face of extreme perturbations and *flexible* in responding to changing circumstances. Sustainability as a *process* of development, not a final state, has ecological, social and economic dimensions. While it is difficult to define that process precisely, it is less difficult to identify *unsustainability*, patterns that place the socio-ecological system at risk of devolution and collapse.

It is useful to separate two dimensions of the sustainability problem -- biophysical and socio-economic. In biophysical terms, sustainability implies the maintenance of ecosystems, bio-geochemical cycles, and the natural resource base at levels that maintain the functional and structural integrity of natural systems. This will mean that they can continue to support human material well-being, provide ecological services and preserve the natural heritage for human appreciation. Beyond these pragmatic goals, many would add as an ethical imperative that the protection of the biosphere is a valid end-in-itself. Biophysical sustainability requires that human activity does not destroy the regenerative capacity of natural capital or irreversibly stress atmospheric, hydrological or terrestrial ecosystems with waste and pollution. Sustainable development, from a biophysical perspective, puts focus on reducing the *throughput* -- flows of materials and energy into and waste out of production and consumption activities -- toward levels that are within renewable resource flows and assimilative capacities of ecosystems. Sustainability implies living on natural “interest”, not drawing down natural capital.

Throughput levels, in turn, are dependent on consumption patterns, population levels, production technologies, land-use management and other factors that determine the requirements for virgin materials and pollution loads. In one sense, the problem of sustainability is the conflict between rising throughput rates, driven by growing economies, and finite biospheric capacities.

In addition to the issue of the scale of biophysical impacts, there are critical socio-economic aspects of sustainability. The notion of social sustainability calls attention to the level and quality of stability, social cohesion and solidarity in society. To the degree that distributional equity, political participation, and access to education, health and cultural services are perceived to be acceptable, a social system will enjoy the commitment, loyalty and affiliation of its participants, and be better prepared to respond to changing endogenous and exogenous circumstances. At the other extreme, a system which is inequitable and coercive tends to be more rigid, prone to conflict and less able to adapt gently to internal or external disturbances.

Finally, economic development may be a precondition for a transition to sustainability. The wide adoption of sustainability principles will require that economic systems and distribution patterns provide basic human needs, reliable livelihoods and freedom from drudgery. Desperate people often focus on immediate survival questions,

and discount the long range value of ecological preservation. The economic development of poor countries and communities to meet these goals is critical to sustainability. Rich countries and communities also have a development challenge -- the transformation of the model of progress from ever-increasing growth in consumption, to a culture of material sufficiency and the growth of quality values through, for example, the resurrection of stronger community ties, more meaningful leisure activities and greater regard for nature.

In general, the concept of socio-economic *development*, the expansion or realization of potentialities, must be distinguished from economic *growth*, or material accretion (Goodland et. al., 1992). The latter is the hallmark of the industrial era and does not appear to be indefinitely maintainable. Human cultural, intellectual, artistic, social and technological development, together with the provision for basic physcial needs, is not only compatible with sustainability, but essential for its realization.

2. Global Scenarios

Long range socio-ecological futures are inherently unpredictable. Three types of indeterminacy can be distinguished. First, insufficient information on both the current state of the system and on forces governing its dynamics lead to a classical statistical dispersion over possible future states. Second, even if precise information were available, complex systems are known to exhibit turbulent behavior, extreme sensitivity to initial conditions and branching behaviors at various thresholds which thwart prediction (Gleick, 1987; Funtowicz and Ravetz, 1993). Finally, the future is unknowable to the degree it is the result of freely determined human choices.

There can be no credible oracle to foretell the future. Nor can the wisest of today's computer models help in assigning probabilities to alternative possibilities. While we cannot know what will be, we can use words and numbers to tell plausible and interesting stories about what could be. In theater parlance, a scenario is a summary of a play. Analogously, the development scenario is a structured narrative for describing the contours of alternative futures. As applied to sustainability studies, the scenario draws on both science -- our understanding of historical patterns, current conditions and physical and social processes -- and the imagination to conceive, articulate and evaluate a range of socio-ecological pathways. In so doing, scenarios can illuminate the relationships within the total system, and the relationship between human actions and the whole complex of interconnected outcomes. It is this added insight, leading to more informed and rational action, that is the foremost goal of scenarios, rather than prediction of the future.

2.1. Many Futures

Images of the future continually shape our sense of the possible, our motivations and our actions. Individual destinies are both a push from the past -- our experiences and our condition drive us forward -- and a pull to the future -- our vision of alternative possibilities draw us forward. The capacity to alter our behaviors based on anticipations of alternative futures adds choice to the determinism of history. This intentionality is perhaps the essence of human freedom and creativity.

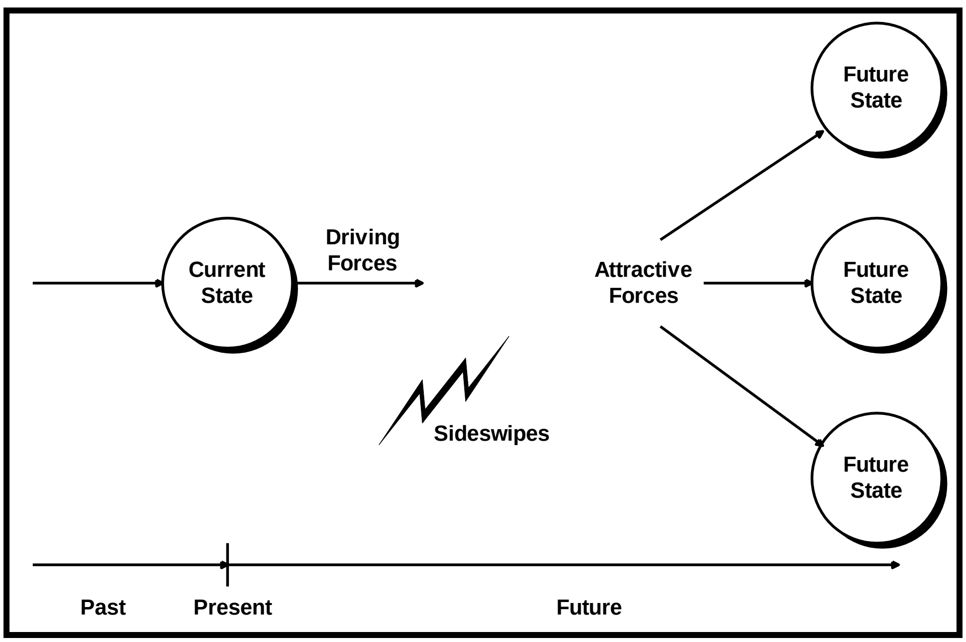
The human psyche seems drawn to speculation about our collective possibilities, as well. Throughout human history, seers, psychics, oracles and prophets have advanced revelatory and often apocalyptic visions of society's future. For centuries social utopians have imagined alternative societies, and sometimes tried to live the dreams. Today, practitioners of magical forms of divination live on in surviving indigenous cultures, in revivalist fundamentalist movements and in the *new age* sub-cultures of industrial societies, while science fiction provides high tech fables to a hungry audience. Meanwhile, more pragmatic forms of futurism are used by consultants helping organizations better position themselves in the world of tomorrow, think-tanks advising on national defense strategies and global analysts examining problems and possibilities for long term sustainability.

To whatever has animated human interest in the future heretofore -- curiosity, advantage, anxiety, a search for meaning -- may be added the very modern concern for passing on an undiminished world to our heirs. Compelling scenarios can contribute to converting this emerging value into understanding and action by providing early warnings of possible dangers, fostering dialog among averse stakeholders and influencing policies and behaviors.

2.2. Driving Forces, Attractors, Sideswipes

The recognition that human choice shapes the future in important ways is not to deny that powerful and persistent factors impel the socio-ecological system forward from the present. Realistic transition scenarios must reflect the initial condition and dynamics that define the point of departure for all future states. The situation is illustrated schematically in Figure 3 which shows the current socio-ecological state subject to initial *driving forces*.

Figure 3 Driving Forces, Attractors, Sideswipes



The scenario narrative is largely a story of how the driving forces evolve. But the system evolution is not only a mechanical unfolding from the past but also subject to human intention. We introduce the teleological concept of *attractive and repulsive forces* in Figure 3. These images, symbols and visions of the future are sufficiently powerful to substantially redirect beliefs, behaviors, policies, and institutions toward some futures and away from others. Attracting attributes of future states might include consistency with sustainability principles -- a future which remains within certain

biophysical *boundary conditions* -- and human well-being -- a future which meets various criteria for human welfare and fulfillment.

Negative images of possible future states also play a role in galvanizing efforts to redirect system evolution away from pathways leading to undesirable outcomes. So a spectrum of scenarios ranging from utopian to dystopian extremes is useful for bringing visions of future possibilities back to the present. In this sense, the attractive and repulsive forces may influence the driving forces and human development.

The final set of interactions illustrated in Figure 3, the *sideswipes*, are surprising future occurences which can powerfully influence, and have in the past, the evolution of the system but are very difficult to predict. Extreme events -- a third world war, the diffusion of cheap nuclear fusion power, the ascendency of fundamentalism as a dominant world movement, a major natural disaster, a rampant global epidemic, a breakdown of the climate system -- would have a strong influence on the global future though probabilities cannot be assigned, nor can the universe of possible events even be described.

2.3. Mega-processes

There are several significant driving forces now operating at the global level. While not inevitably persistent, these transnational trends condition the initial direction for the socio-ecological system. Significant mega-processes include population growth, urbanization, economic globalization, cultural homogenization, environmental degradation and technological innovation. Together, they are strongly interacting aspects of a unitary global phenomenon, the advance of the conventional mode of development.

Global population will nearly double to over ten billion people by the year 2050, according to mid-range United Nations forecasts (Bulatao et al., 1989; United Nations, 1992a; UNPF, 1995). Fully 95 percent of the additional population will be in developing countries where population is projected to grow from about 4 billion in 1990 to 8.6 billion in 2050. Although the linkages between population growth and the environment are not straightforward, in many instances population growth can add to environmental and resource pressure, undermine development, and ultimately increase the risk of social friction, illegal migration, and international tension. With current populations heavily weighted toward the young in poor regions, there is a built in momentum for growth. Almost half of the projected population growth in developing countries would occur even if fertility rates instantly decreased to replacement levels (Bongaarts, 1994).

The relationships among population growth, human development and environmental degradation are highly varied and controversial (Raskin, 1995). Some stress the primacy of population growth in undermining sustainable forms of development (Paddock and Paddock, 1967; Ehrlich, 1968; Brown, 1978; Ehrlich and Ehrlich, 1990), while at the other extreme “optimists” see no inherent problem since the carrying capacity

of natural systems can be indefinitely expanded through technological and institutional ingenuity (Kuznets, 1967; Kahn et. al., 1976). Others regard population as secondary in this context stressing instead the large disparity -- up to a factor of ten -- between countries in per capita levels of consumption and resources appropriation (Chadwick, 1994), with the consumption gap widening both between and within countries (UNDP, 1993).

Nevertheless, for a given set of socio-economic development conditions, population growth increases the pressure on resources and the environment. This effect is most pronounced among the very rich, where each additional person accounts for huge resource and environmental investments, and the desperately poor, where the rationality of survival may imply the liquidation of natural capital to meet immediate needs.

Rapid urbanization is a second major trend. The world is in the midst of a massive planetary transition from a predominately rural to heavily urban society. The pattern is summarized in Table 1. Urban population increased between 1950 and 1990 by a factor of 3. The figures suggest that substantial further growth can be expected. Most of the urban population growth of 2.9 billion projected for 2025 is in developing regions, 1.7 billion additional in Asia, 0.7 billion additional in Africa, and 0.3 billion additional in Latin America. At the current time, 85% of additional population is urban, as the fraction of total population continues to rise from less than 50% today to nearly 70% projected for 2025 (United Nations, 1991).

Table 1
Actual and Projected Urban Populations (Billions)

Region	**1950**	**1990**	**2025**
World	.8	2.3	5.2
Developing Regions	.3	1.5	4.2

Source: WRI (1994)

The number and size of huge megacities has expanded apace. In 1950 there were two metropolitan areas with populations over eight million, New York and London (Harrison, 1992). By the year 1990 there were twenty (fourteen in developing countries). By 2000, there will be fifteen to twenty megacities with population over 20 million. Almost universally, urban planning institutions have been too weak to cope with rapid urban growth, turning towns into cities, cities into megacities, and, if current trends continue, megacities into conurbations -- continuous networks of urban centers. The deterioration of inner cities in some areas and the growth of shanty towns on the periphery in others, undermines social cohesion with the visible rise of social disparities, crime and violence. The elite adopt affluent urban life styles amidst a growing underclass living in squalor, often with inadequate sanitary, health and educational services. Moreover, urban tensions foster the suburbanization process and the rise of the automobile culture with its toll on land, the environment and the social fabric.

The expansion and transformation of the world economy is another significant transnational process governing the evolution of the world system. Accelerated by advances in information technology and the growth of international trade agreements, the organization of production, consumer and financial markets is becoming progressively *globalized*. Two fundamental trends -- the emergence of new national economic powers and the growth in transnational corporations -- will alter the political and economic landscape in the coming decades.

The world economy is becoming more regionally pluralistic as economies expand in developing countries, Japan and the European Union. The economy of China could pass that of the United States in the next twenty years, with other Asian and Latin American countries becoming progressively more significant players in the global economy. Under mid-range economic projections, the size of the economies of developing countries taken in aggregate in 2025 will be about the size of all industrial countries today.

Interacting with the emergence of new national centers is the second structural transition, the increasing role of transnational corporations. The growth of huge enterprises operating in a planetary marketplace is a natural extension of the expansionist dynamic inherent in competitive market systems. Beyond the growth of the world economy itself, technological and institutional factors have accelerated the transition from national to transnational corporations. The revolutions in communications technology, information processing, and transportation have facilitated the ability of transnationals to move facilities, products and people to their best advantage (Reich, 1991).

At the same time, new trade agreements and the globalization of financial and currency markets have combined with post-World War II economic liberalization trends to challenge residual protectionist restrictions. Meanwhile, the expansion of modern infrastructure and stable legal frameworks facilitate the globalization process. An unusual coalition of forces resists these trends including nationally based economic interests, geopolitical isolationists and environmentalists who raise nontrivial concerns about the impact of global competition on environmental protection and community stability (Daly, 1993). There is significant potential for political tensions to grow between *stateless corporations* with little allegiance to any country and the nation-state of the 21st century. Whether these tensions resolve through a gradual balancing of global and national governance and regulatory structures, or whether they are the source of clashes and destabilization, will be an imporant sub-theme in the story of the 21st century (Wager, 1992).

There are contrary phenomena manifest, as well, in the area of cultural change. Catalyzed by the explosion of information technology and ubiquity of electronic media, American consumer culture is rapidly permeating many societies. The rise of a global consumerist culture -- acquisitive, youth-oriented, hedonistic -- is both a result and a

driver of economic globalization. At the same time, the forces of global cultural homogenization trigger reactions that can increase tensions between and within nations, while reducing cultural diversity. While apparently contrary phenomena, the simultaneous advance of a single global marketplace, on the one hand, and national, racial and religious movements, on the other, are dialectically interconnected, with each posing important challenges to democratic institutions (Barber, 1995).

The awareness of environmental degradation as a transnational process is a cardinal phenomenon of our era, and may be considered another significant transnational driving force. International concern has grown about human impacts on the atmospheric, land, and water resources, the bio-accumulation of toxic substances, species loss, and the degradation of ecosystems. The cumulative effects of global environmental insults cannot be known precisely but could have significant detrimental effects on economic performance, human health, social stability, and even international security. The realization that individual countries cannot insulate themselves from global environmental impacts is changing the basis on which developed countries provide foreign assistance and stimulating a series of international discussions and treaties to abate pressures on natural systems, possible a harbinger of new forms of global governance.

Finally, several *next wave* technological innovations and trends may be identified that have the potential for significantly effecting global dynamics. Information technology (IT) -- computers, the internet, telecommunications -- was identified above as a catalyst for the globalization of financial, labor, and product markets. IT will likely continue to impact massively the structure of production units (down-sizing, just-in-time manufacturing), the nature of work (telecommuting, marketing and sales techniques) and leisure time (home shopping, interactive gaming, media access). The technology also has the potential to exacerbate tensions within and between societies who are excluded from the largess of the *information superhighway*, or resent its implications for the preservation of traditional cultural values.

Advances in biotechnology could have an array of significant effects on future society including increased crop yields with lower chemical inputs, more effective pharmaceuticals, and, if the human gene is successfully mapped, identifying and preventing disease. The technology also raises a host of environmental risks (e.g., introduction of bio-engineered genomic material in plants that leads to population explosions and centers of disease resistance), ethical problems (e.g., the genetic engineering of children) and political and economic concerns (e.g., new forms of dependency of developing countries on the international agro-industrial system).

Lastly, the miniaturization of mechanics -- *microdynamics* -- could fundamentally alter medicine and some industrial processes (NSF, 1989). The ultimate in this direction would be *nanotechnology*, the engineering of computers, motors and machines at the molecular level. While still in the early stages of research and development, nanodevices

could revolutionize medical practices, material science, computer performance and many other applications. In one sense, nanotechnology could be a dramatic continuation of the twentieth century process of dematerialization, where progressively less material input is required per unit product, and automation, where smart machines replace manual labor. In addition to its effects on products, nanotechnology -- along with other technological development -- can diminish environmental pressure and reduce labor requirements through robotization . The latter, if not linked to a general scaling back of average work loads, could radically reduce livelihood and employment opportunities. In general, these productivity enhancing technologies could have a profound effect on future societies with the potential both for increasing wealth while eliminating drudgery and environmental pressure or -- if not coupled to other social and cultural changes -- of enormous social displacement.

2.4. Approaches and Frameworks

The use of words and numbers to tell interesting stories about what could be, without suggesting a prediction of the future, has a well worked history. Scenario development, as a tool to explore "what if" questions, requires a disciplined and systematic approach. Of major concern are the boundaries and the internal structure of the system. At some stage in scenario development computer-aided models usually are needed to provide the overall framework of system linkages and to allow the input and manipulation of data. Model-based scenarios can aid the understanding of complex phenomena and reveal the nature of the interaction between a wide range of elements and interests.

Scenarios, together with models, have been used over the last twenty years or so to investigate a wide range of issues. These span interests in 'limits to growth'-type problems (Forrester, 1971; Meadows et al., 1972, 1974; Marchetti, 1978), regional development-related problems (Mesarovic & Pestel, 1974; Kaya et al., 1980), sectorally-linked issues (Fischer et al., 1988; Linnemann et al., 1979), the role of surprise in determining development trajectories (Svedin & Aniansson, 1987), policy options and obstacles (Herrera et al., 1976), nuclear winter or catastrophe scenarios (SCOPE, 1985) and the climate warming scenarios of the IPCC.

The time-span, method of investigation, structure and manipulative potential, as well as the results and conclusions, of these models have been evaluated elsewhere (Meadows et al., 1982; Chadwick, 1994). It is difficult to avoid the conclusion that where the models emphasized physical limits, including environmental sinks, the lessons taken were often unnecessarily pessimistic. A corollary of this is the necessity of embedding economic, political, institutional and social factors in the scenarios and model runs so that linkage and feedback features are included. Ways of doing this are now emphasizing simplicity, transparency, and the ability to iterate within a framework that allows economic, resource and environmental information to be included in generating development scenarios (Raskin et al.,1995b).

2.5. A Taxonomy of Scenarios

A range of idealized visions of long-range development is introduced in Table 2. Each picture of the future is characterized by an overall development paradigm, and demographic, economic and technology assumptions.[2] A full scenario would include a description of the temporal sequence leading to a future state. The narrative would include both *forecasting* the near term development pathway and *backcasting* from possible end-states to lay out a plausible development story, a kind of *history of the future*. Such scenarios might include transitions from one type of development paradigm to another, or to mixtures of states.

The *conventional development* category of scenarios posits a world in which economic, technological and institutional trends unfold in a continuous manner, governed by the global mega-processes described above. According to the conventional development paradigm (Section 1.3), the values and institutions of industrial culture gradually penetrate all regions. The remainder of this study examines the uncertainties and stress points of such a scenario.

The *technology push* scenario assumes the life-styles, values, demographic and land-use patterns, and distributional inequities of the conventional development scenario. In addition, the scenario assumes a fundamental shift in policies for promoting the rapid development and deployment of technologies that are highly environmentally friendly. This scenario posits a mobilization of political will, perhaps in the face of deepening environmental threats, for a transition to deep efficiency in the use of energy, water and other resources; clean industrial processes; renewable sources of energy; sustainable farming and forestry practices; and recycling of solid waste and remanufacturing of durable goods.

The *technology push* scenario is useful for examining the degree to which the pressures on sustainability arising from conventional development can be relieved through technology alone. However, the scenario does not address the problematic social aspects of conventional development. The *rapid growth with equity* scenario begins to address this question by assuming a world in which conventional development values and life-styles prevail, but there is a much stronger convergence of development between the poor and rich countries. Accelerated industrialization throughout the developing world is fostered by a combination of economic globalization led by transnational corporations, concerted international policy, strengthening of market and financial institutions, and open technology transfer. Aggregate consumption levels are driven higher as average per capita incomes increase but partially offset by a moderation in population growth as a consequence of modernization.

[2] Other organizing structures for global scenarios are presented in, e.g., Kahn. et. al. (1976), Robertson (1979), Svedin and Aniansson (1987), Burrows et. al. (1991), and von Asselt and Rotmans (1995).

The *technology push* and *rapid growth with equity* scenarios -- and combinations of them -- help explore the scope for technology to ease environmental pressure and the implications of greater international equity (not necessarily national equity). These scenarios may or may not meet sustainability criteria. Furthermore, they leave invariant normative aspects of the conventional development world relating to the quality of life. A world of high technology and high consumerism represents a certain normative perspective, and an unsettling vision of the future for those concerned with the quality of human communities, the psychic worth of the experience of nature, the meaning of work, and the importance of spiritual values. Expansion of wealth can coexist with the impoverishment of culture, a lack of individual fulfillment and widespread angst and anomie.

The utopian *new sustainability paradigm* set of scenarios is introduced with the aim of sketching a qualitative alternative to the conventional development paradigm. Here a transition is assumed to a world in which new democratic governance structures evolve which are matched to the sustainability requirements of socio-ecological systems at local, regional and global levels. A pluralistic world system is assumed to incorporate both markets and regulation, a variety of cultures, and a rise in a sense of human solidarity at community and global scales. The emergence of more dispersed settlement patterns drives a de-urbanization trend, as communities which integrate work and personal life become more popular. Population growth moderates with the rise of the sustainability world-view, the empowerment of women and a more equitable distribution of wealth. The consumerist thrust is supplanted by a philosophy of voluntary simplicity which seeks a comfortable, but not profligate, level of material well-being, as society strives for a high degree of economic and social equality. Small scale technology and greater degrees of regional self-reliance complement global infrastructures and trade, which have a significant residual role in a solar-driven economy.

Dystopian futures must also be imagined. The *breakdown* scenario assumes a collapse of the global economy with severe environmental disruption as memory of twentieth century culture withers, authority disintegrates and society descends into fragmented and violent remnants. By contrast, the *authoritarian* scenario assumes that centralist political formations are ascendant in affluent areas, including pockets within developing countries. This is a fortress world of extreme distributional inequity, with enclaves of privilege behind guarded walls (adumbrated by the growing number of *gated* communities in today's polarized social world) and a large underclass resorting to crime and asocial behavior.

Finally, *bombshell* scenarios are dominated by the effects of the sideswipe shocks of surprising events (illustrated in Figure 3). If history is a guide, significant technological, social, natural and geo-political surprises are likely over the fifty year period we are considering (Toth et al., 1989). What are the implications for global scenario analysis of the recognition that the future might hold big surprises? It is clear that in our thinking about the long-range future, our conclusions must be tentative, and

our perspectives must be continually renormalized as events evolve. Like navigators responding to unforeseen conditions, we must continually monitor and revise our directions in light of new information.

The better we grasp where we are headed, or could be headed, in a world without course-altering shocks, the better we can consider the impacts of extreme events, and perhaps take steps to reduce the probability of undesirable surprises (e.g., runaway climate effects driven by anthropogenic greenhouse gas emissions) and foster others (e.g., through research and development on cutting-edge technologies). The possibility of unforeseen jolts invites the adoption of development strategies that build resilience into technical, natural and institutional systems so that the vulnerability to perturbations and the danger of breakdown are reduced.

Table 2 Idealized World Development Visions

Scenario	Development Paradigm	Population	Economy	Technology
Conventional Development	Conventional industrial model; gradual economic globalization; nation states remain primary with rise in representational democracy; market and consumerist driven	Mid-range; aging population in industrialized countries; rapid urbanization in DCs	Gradual growth; shift to service sector; slow reduction in North-South gap	Gradual adjustment
Technology Push	Conventional with strong policies to stimulate clean technologies	“	“	Best available technology
Rapid Growth With Equity	Accelerated globalization; convergence of international economies; emergence of multiple regional blocs; rapid expansion of industrial culture, markets, technology and values	Low-range; converging demographic structures	Rapid expansion; rapid reduction of North-South gap; led by multi-national corporations	Rapid development; technology transfer
New Sustainability Paradigm	New governance structures with reduced role for nation state; combined markets with planning constraints; rapid rise of community, quality and equity values	Low-range; more dispersed settlement patterns	Low growth; approach to steady state and equity; more local reliance within global system; reduced consumerism; voluntary simplicity	Mixed small and large scale; global infrastructure; clean technology
Breakdown	Severe economic-environmental-social crises; collapse of world economy; social disorder; extreme localism; deindustrialization	Decreasing	Formal economy shrinks as informal production and barter expand	Increasing use of manual implements; simple technologies in informal economy
Authoritarian	Corporatist response to breakdown; centralized command & control; enforced environmentalism	Low-range enforced	Controlled growth; enforced simplicity; distributional inequity	Large scale high-tech in elite fortresses; devolution elsewhere
Bombshells	Extreme perturbations, e.g., due to pandemic, “miracle” technology, dominance of world fundamentalist religion, World War III, colonization of space, runaway climate change, etc.			

2.6. *Destiny or Opportunity*

There are those who downplay concerns about sustainability. Many hold philosophic objections to grand attempts to understand and guide human destiny, placing their faith in the capacity of the free market, human ingenuity and a homeostatic biosphere to provide timely responses to environmental and resource pressures. This world-view suggests minimalism toward development and environment policies, beyond steps to get competitive and maximally unfettered markets to function at local, national and global scales. Indeed, this perspective is ascendant in many arenas, especially where economists of the neoclassical school advise governments and formulate policy (Beckerman, 1995).

From the perspective of many ecologists and adherents of the sustainable development paradigm, this emphasis seems dangerously naive. The risks of relying on market and natural responses to correct perilous tendencies -- and being wrong -- are huge. The adoption of proactive policies and actions to avoid risks of ecological breakdown, resource degradation and related social friction appears the only prudent course under conditions of such uncertainty.

A major problem in joining these frameworks is the incommensurability of monetary costs as defined by markets, and environmental costs which are often long-term, multi-dimensional, and inherently normative (e.g., the cost of an "excess death" or of a lost species). There is no consensus, or even compelling methodology, for comparing the costs of climate change, for example, to the monetary costs of preventing it. Furthermore, there are great difficulties in embracing the interests of future generations -- who cannot "vote" in today's market place -- with the immediate bottom-line concerns of today's producers and consumers.

In the end, the notion of sustaining the planet itself is a value that cannot be derived from economic doctrine. For those who adopt this value, a minimum requirement for policy will be to reduce the risk of undermining the conditions for human opportunity and activity in the future. We are at the early stages of operationalizing sustainability as a practical basis for action. This will require defining sustainability targets, laying out development scenarios that conform to those targets, and fashioning policy strategies for achieving goals.

3. A Conventional Development Scenario

A key initial step in the process of building rich scenarios of the future is to evaluate critically the implications for the future of current trends, policies and orthodox notions of development. To that end, we introduce in this section, and critically evaluate in the next, a *conventional development scenario* (CDS) for global development.

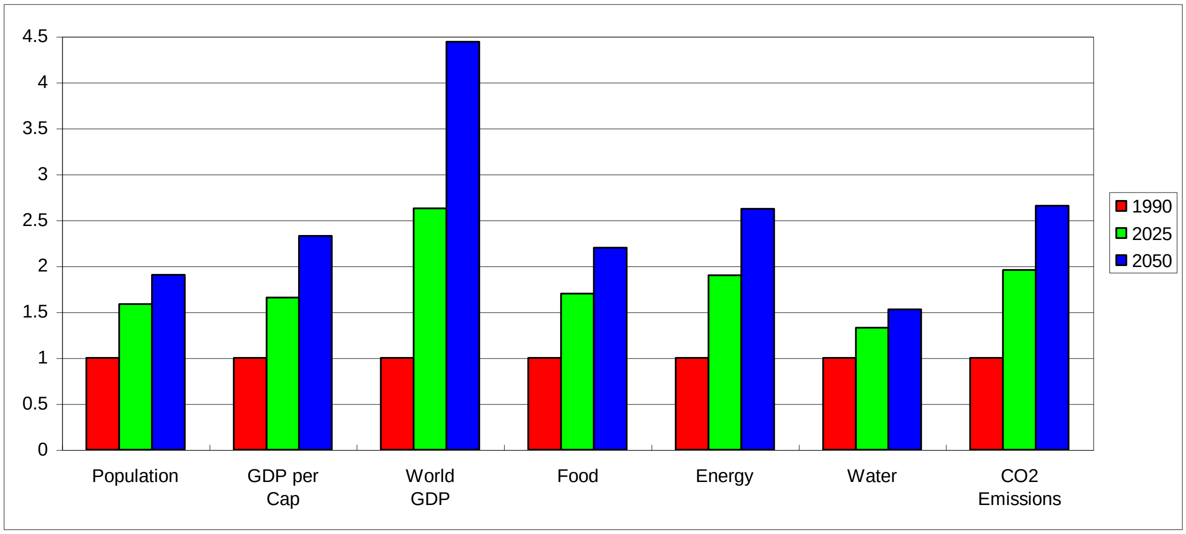
The CDS is a narrative about the future, told in words and numbers, guided by the world view described in Sections 1.3 and 2.5. The CDS we examine here is compatible with the mid-range scenarios of the Intergovernmental Panel on Climate Change (IPCC, 1990; IPCC 1992). The IPCC exercise included an extensive international process that involved analysts representing all regions of the world. The results have received an unprecedented level of dissemination and discussion, with ample opportunity for comment and critique. The scenarios have become something of a standard reference for energy and climate research in recent years. The CDS addresses a much wider range of resource, environment and development issues, but relies on the IPCC scenario[3] -- which incorporates mid-range United Nations and World Bank projections on such variables as population and economic growth -- for broad assumptions underlying a conventional development picture.

3.1. The Scenario: A Bird's-eye View

The scenario is summarized by a set of global indicators in Figure 4. The CDS is shown to be a world of rapid expansion of human activity. By the year 2050, population nearly doubles relative to 1990, income (expressed as GDP per capita) more than doubles, and world economic output more than quadruples. Food requirements more than double driven by population growth and assumed income increases. Requirements for energy and water increase at a slower rate than economic output, by a factor of 2.5 and 1.5, respectively, over the period. The decrease in aggregate energy and water intensities (requirements per unit of GDP) is traced both to increasing use efficiencies and gradual shifts to less resource intensive economic activities.

[3] Specifically, the IPCC "base case" scenario -- referred to as "business-as-usual" in the 1990 report and simply as IS92A in the 1992 update.

Figure 4 Global Patterns in the CDS



The environmental implications of the scenario are extremely complex and range over large spatial scales and diverse environmental media. As a crude indicator, we display carbon dioxide emissions (CO_2) from energy (a primary contributor to the risk of global climate change) in Figure 4. Total CO_2 emissions increase substantially over the scenario period, by a factor of 2.7, from 20 Gt in 1990 to 52 Gt in 2050.[4] We return below to a more detailed discussion of resource and environmental pressures.

3.2. Regionalization

The *spatial structure* for long range global assessment requires enough resolution for exploring important global variations and trade patterns, while not exceeding the availability of data and the capacity to grasp the main contours of the global system. For purposes of this analysis, we have grouped countries into ten global regions, based on the comparability of socio-economic development and geopolitical considerations. The regional groupings and the countries included in each are displayed in Table 3.

There are many alternative ways of defining global regions, e.g., by dominant religio-cultural practices, by agro-ecological zones, by river basin, by socio-economic system. Furthermore, there is never a sharp demarcation between regions, so certain countries can arguably be moved from one region to another without doing violence to the analysis. No configurations are without conceptual complications and daunting data problems. For example, the anachronism of defining the Former Soviet Union as a region is necessary for now because that is the way data have been organized historically. The regional structure employed here is reasonably manageable while preserving sufficient

[4] CO_2 emissions are often expressed in the literature in terms of carbon content (1Gt C-CO_2 = 3.67 Gt CO_2).

Table 3 Regional Structure

North America
U.S.A.
Canada

Western Europe
Austria
Belgium
Denmark
Finland
France
Germany (All)
Greece
Greenland
Iceland
Ireland
Italy
Luxembourg
Netherlands
Norway
Portugal
Spain
Sweden
Switzerland
Turkey
United Kingdom
Yugoslavia

OECD Pacific
Australia
Fiji
Japan
New Zealand

Former Soviet Union (FSU)
Former Soviet Union
And Baltic States

Eastern Europe
Albania
Bulgaria
Czechoslovakia
Hungary
Poland
Romania

Africa
Algeria
Angola
Benin
Botswana
Burkina Faso
Burundi
Cameroon
Central African Republic
Chad
Congo
Egypt
Ethiopia
Gabon
Gambia
Ghana
Guinea
Guinea Bissau
Ivory Coast
Kenya
Lesotho
Liberia
Libya
Madagascar
Malawi
Mali
Mauritania
Mauritius
Morocco
Mozambique
Namibia
Niger
Nigeria

Africa (con)
Reunion
Rwanda
Senegal
Sierra Leone
Somalia
South Africa
Sudan
Swaziland
Tanzania
Togo
Tunisia
Uganda
Zaire
Zambia
Zimbabwe

Latin America
Argentina
Bolivia
Brazil
Chile
Colombia
Costa Rica
Cuba
Dominican Republic
Ecuador
El Salvador
Guatemala
Guyana
Haiti
Honduras
Jamaica
Mexico
Nicaragua
Panama
Paraguay
Peru
Surinam
Trinidad & Tobago
Uruguay
Venezuela

Middle East
Afghanistan
Bahrain
Cyprus
Iran
Iraq
Israel
Jordan
Kuwait
Lebanon
Oman
Qatar
Saudi Arabia
Syria
United Arab Emirates
Yemen

China +
China
Korea, Dpr
Laos
Mongolia
Vietnam

South & East Asia (S&E Asia)
Bangladesh
Bhutan
Brunei
Burma
Hong Kong
India
Indonesia
Kampuchea
Korea, Republic Of
Malaysia
Nepal
Pakistan
Papua New Guinea
Philippines
Singapore
Sri Lanka
Taiwan
Thailand

spatial detail for the purposes of understanding major global interactions and trends.

3.3. Demographic Projections

Regional population projections for the CDS are presented in Table 4. In these mid-range projections, world population nearly doubles, reaching a value of just over 10 billion people by the year 2050. Ninety-five percent of the projected global population increase of 4.7 billion occurs in developing regions. By contrast, populations in "industrial" and "transitional" regions[5] are relatively stable in the scenarios, as their share of world population decreases from about 20% to 13%.

Table 4 Population Projections (Millions)

Region	1990	2025	2050	Growth Rate (%/Year) 1990-2025	2025-2050
North America	277	330	322	0.5%	-0.1%
Western Europe	456	489	477	0.2%	-0.1%
OECD Pacific	145	161	157	0.3%	-0.1%
Former Soviet Union	289	332	349	0.4%	0.2%
Eastern Europe	100	115	121	0.4%	0.2%
Africa	640	1,519	2,204	2.5%	1.5%
Latin America	445	699	812	1.3%	0.6%
Middle East	151	384	557	2.7%	1.5%
China +	1,223	1,733	1,867	1.0%	0.3%
South & East Asia	1,564	2,634	3,214	1.5%	0.8%
World	5,290	8,395	10,080	1.3%	0.7%
Industrial	878	980	956	0.3%	-0.1%
Transitional	389	447	470	0.4%	0.2%
Developing	4,023	6,968	8,654	1.6%	0.9%

Source: Figures for 1990 from the World Bank (1993); projections from World Bank analysis (Bulatao, 1989) and the United Nations (1992).

Population projections are sensitive to the assumed trend in total fertility rate (the number of children per female), particularly in developing regions. The mid-range projection assumes that the TFR approaches the replacement rate in the mid-21st century, the value (about 2.06) at which populations become stable. If the TFR is assumed to approach 2.17 over the next century, for example, population projections would rise to about 13 billion by 2050 (Haub, 1994). Future fertility rates will depend on such factors as the character of economic development, the status of women, the degree of persistence of traditional cultural patterns, and disease incidence. In the spirit of the CDS, we assume

[5] We sometimes use the terms "industrial" for the three OECD regions and "transitional" for the FSU and Eastern Europe regions.

mid-range projections which incorporate a gradual global transition to “modern” developed country population patterns and socio-economic patterns.

3.4. Economic Growth

The standard measure of macroeconomic scale is *gross domestic product*. In essence, the GDP is an expression of market transactions. Following a basic economic identity, GDP can be expressed equivalently as consumption (e.g., final demands for households, government, capital investment and net exports) or production (e.g., value added in industry, services and agriculture), providing a useful account of the components of each.

GDP is a flawed measure of economic development for several reasons. First, the data are not of comparable quality across countries. For example, unreported transactions in “informal” or illegal economic activities may be substantial in many areas, or costs and prices not set by markets as in the FSU (World Bank, 1993b; Daly and Cobb, 1989; Brown et al., 1991). Second, cross-country comparisons require the application of an exchange rate in order to express national figures on a common scale. While GDPs are generally reported in US dollars using official currency exchange rates, the alternative “purchasing power parity” converts currency figures based on the costs in local currency of a comparable basket of goods. The PPP conversions generally lead to higher income assignments to developing countries (World Bank, 1993b; United Nations, 1986).

Finally, the GDP is an improper measure of socio-economic well-being since significant costs “external” to markets are not deducted (e.g., degradation of the environment, depletion of natural resource, erosion of community amenities), while “defensive” expenditures are included (e.g., crime control, pollution clean-up, international security) (Daly and Cobb, 1989). So for example, if the environmental release of chemical toxics were to increase suddenly, so would GDP insofar as the additional pollution induced more purchases of bottled drinking water, higher expenditures on environmental remediation, and additional costs for medical treatment.

These difficulties notwithstanding, GDP data remains the most complete accounting of production and consumption activities available[6]. It is employed in virtually all analyses of long-range patterns of economic development, and associated resource and environmental trends. However, using GDP to represent economic trends, it must be borne in mind that, because of the deficiencies identified above, it is a limited

[6] The PPP converted figures provide a better picture of aggregate purchasing power but do not include adjusted measures of production disaggregated by economic activity. Other aggregate measures, such as the Human Development Index (UNDP, 1990), and the Index of Sustainable Economic Welfare (Daly and Cobb, 1989) incorporate useful supplementary information.

measure of economic performance, and a crude and approximate basis for inter-regional comparisons.

Current values and typical mid-range projections of GDP are shown in Table 5, along with average annual growth rates over the periods 1990-2025 and 2025-2050. Rates of growth are seen to be somewhat more rapid in the developing regions than the industrial and transitional regions. The industrial region share of gross world product decreases -- from about 80% in 1990 to 60% in 2050.

Table 5 GDP Projections (Billions US $1990)

				Growth Rate (%/Year)	
Region	**1990**	**2025**	**2050**	**1990-2025**	**2025-2050**
N America	6,040	14,884	21,063	2.6%	1.4%
W Europe	7,171	15,917	23,660	2.3%	1.6%
OECD Pac	3,524	8,100	11,748	2.4%	1.5%
FSU	854	1,898	2,756	2.3%	1.5%
E Europe	210	467	679	2.3%	1.5%
Africa	401	1,657	4,245	4.1%	3.8%
LatinAmer	994	3,018	6,038	3.2%	2.8%
MidEast	541	2,237	5,071	4.1%	3.3%
China +	451	2,698	6,391	5.2%	3.5%
S&SE Asia	1,043	4,943	12,631	4.5%	3.8%
World	21,230	55,820	94,282	2.8%	2.1%
Industrial	16,735	38,901	56,471	2.4%	1.5%
Transitional	1,065	2,366	3,435	2.3%	1.5%
Developing	3,430	14,553	34,376	4.2%	3.5%

Source: Figures for 1990 from the World Bank (1993); growth rates from IPCC (1992a), which are generally within the range of World Bank projections.

To illustrate the income and equity implications of these projections, *GDP per capita* is reported in Table 6. Also shown are growth rates in GDP per capita, which because of high population growth rates, are significantly less that total GDP growth rates in developing countries. The projections show a very gradual North-South convergence in the sense that the ratio of average GDP per capita in industrial regions to developing regions decreases from 22 to 15. However, the *absolute difference* in average per capita income increases substantially. Comparing industrial and developing regions, this difference rises from about 18,000 $/capita in 1990 to 55,000 $/capita by 2050 as northern incomes soar. The conventional development world remains a profoundly inequitable one.

Table 6 GDP per Capita Projections (US $1990)

				Growth Rate (%/Year)	
Region	**1990**	**2025**	**2050**	**1990-2025**	**2025-2050**
N America	21,804	45,127	65,477	2.1%	1.5%
W Europe	15,726	32,548	49,607	2.1%	1.7%
OECD Pac	24,304	50,301	74,803	2.1%	1.6%
FSU	2,956	5,712	7,889	1.9%	1.3%
E Europe	2,108	4,073	5,626	1.9%	1.3%
Africa	626	1,091	1,926	1.6%	2.3%
LatinAmer	2,233	4,315	7,435	1.9%	2.2%
MidEast	3,585	5,832	9,110	1.4%	1.8%
China +	369	1,557	3,423	4.2%	3.2%
S&SE Asia	667	1,877	3,930	3.0%	3.0%
World	4,013	6,649	9,354	1.5%	1.4%
Industrial	19,060	39,699	59,089	2.1%	1.6%
Transition	2,738	5,292	7,308	1.9%	1.3%
Developing	853	2,089	3,972	2.6%	2.6%

Source: Figures for 1990 from the World Bank (1993a); growth rates from IPCC (1992a).

The GDP figures are aggregate measures of economic scale. In the CDS, the composition of economic output is assumed to change also along with gradual adjustments in consumption patterns. In the OECD regions, the service sector provides an increasing *share* of overall economic activity, while agriculture and industrial shares decrease. In addition, the scenario captures the leveling in advanced industrial countries of the per capita growth of material consumption over recent decades (Williams et al., 1987; Bernardini and Galli, 1993), as the subsectoral composition of industrial production adjust with time. Output per capita of materials intensive industries (e.g., iron and steel, non-ferrous metals, non-metallic minerals, paper and pulp, and chemicals), is assumed to stabilize and in some cases decrease. Non-OECD regions are assumed to converge toward OECD economic structures with increasing GDP per capita. A detailed description of the economic assumptions is presented in a companion volume (Raskin and Margolis, 1995).

3.5. Energy Requirements

Abundant, versatile and inexpensive sources of energy are essential to modern industrial economies. But the age of easy energy is over. The production and use of energy figures prominently in many of our most serious environmental problems, while the most accessible and least costly fossil fuel resources are depleted. Environmental,

resource, economic and institutional problems will constrain the continued expansion of conventional forms of energy at historic rates.[7]

Energy demand in the conventional development scenario depends on changing levels of activity (e.g., household appliances, industrial production, transportation, commercial output), energy intensities (demand per unit of activity), and fuel mixes (share of final demand supplied by electricity, oil, coal, etc.). Activities are driven by the demographic, economic and behavioral factors. Energy intensities and fuels used for each activity adjust in the course of economic development and technological evolution, and as a result of changing energy policies and costs. Since the analysis assumes a conventional development framework, continuity may be assumed for these factors. Historic patterns evolve in industrial regions as developing countries gradually approach industrial region patterns.

CDS energy demands grow significantly globally and across all regions. As illustrated in Figure 5, global demand increases by a factor of 2.7 between 1990 and 2050 (from 250 EJ to 680 EJ[8]). There is significant growth in requirements for all conventional fuels, with the most rapid growth for coal, where demand increases by a factor of 4.1 between 1990 and 2050, and electricity, where demand increases by a factor of 3.7. Changing demands and fuel composition for each region are shown in Figure 6. A striking feature is the dramatic increase in energy demand in developing countries. Between 1990 and 2050 energy demand in the scenario increases by more than a factor of 6 in China+, and by more than a factor of 5 in Africa, Middle East and South and South East Asia. Coal use skyrockets in China+ from about 15 EJ in 1990 to about 100 EJ by 2050.

[7] The energy and environment discussion presented in this report summarize Raskin and Margolis (1995), where technical details can be found.

[8] 1 exajoule (EJ) = 10^{18} Joules = 22.3 million tonnes oil equivalent (toe).

Figure 5 Global Energy Demand by Fuel

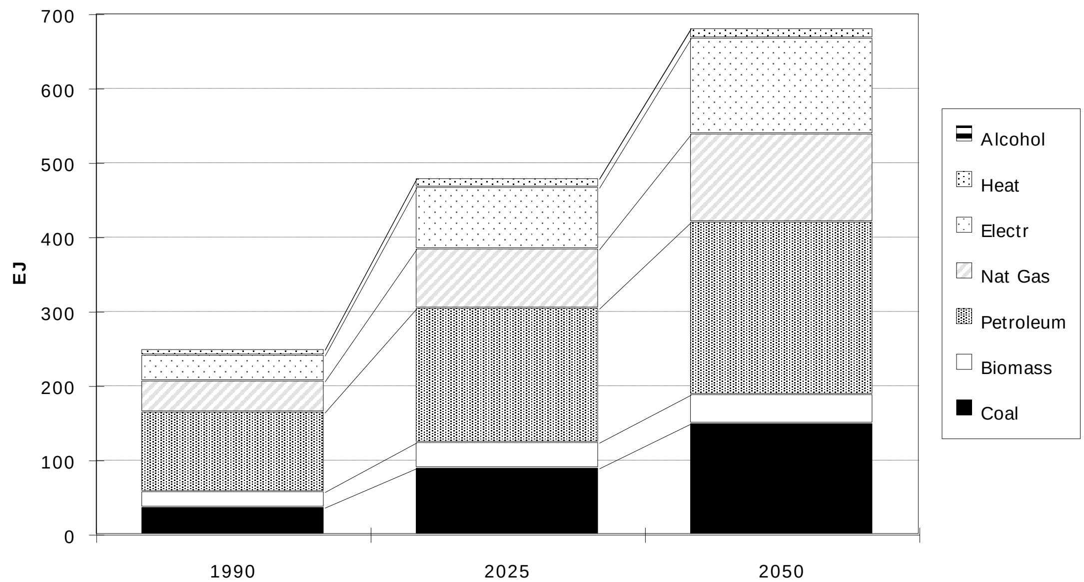
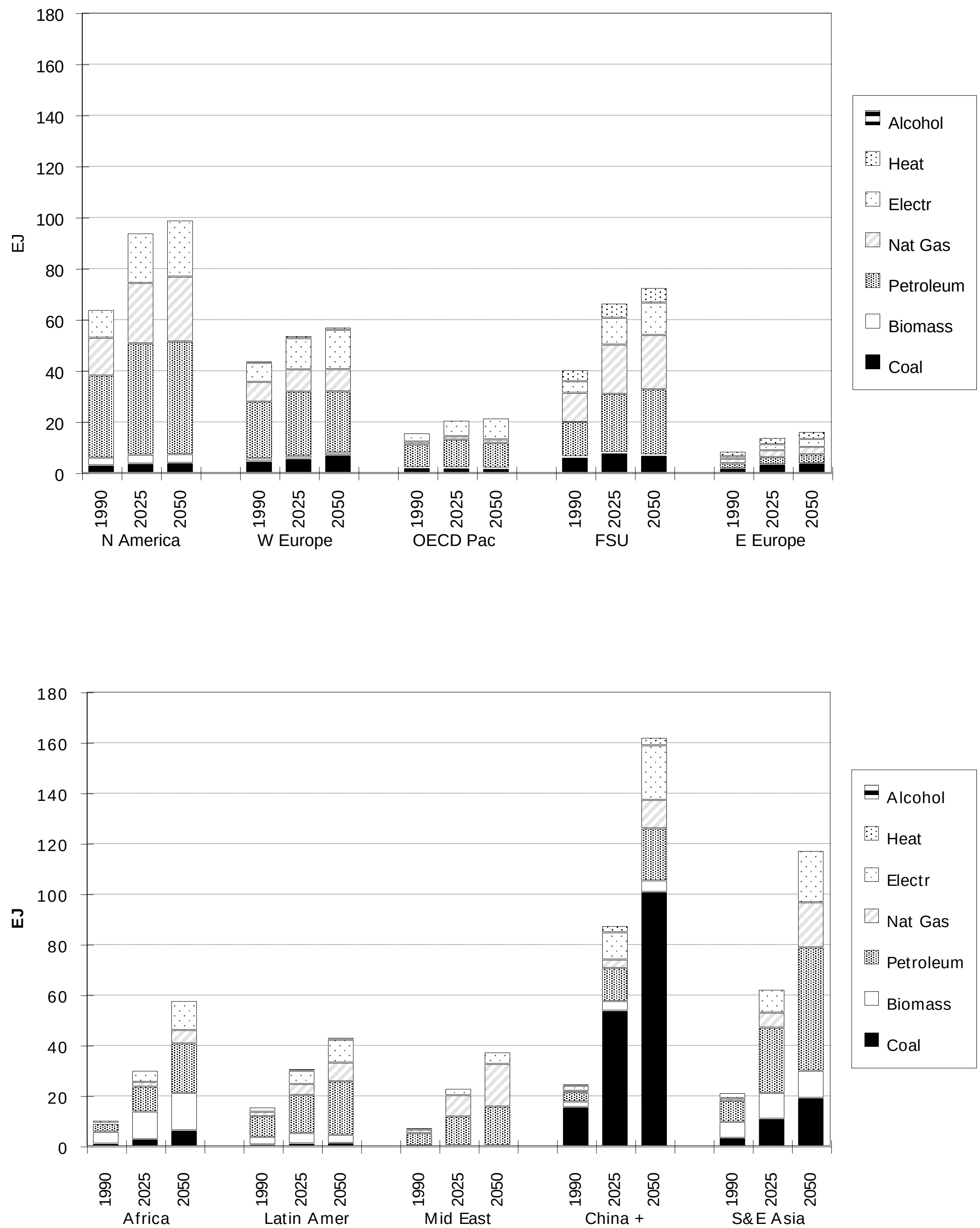


Figure 6 Energy Demand by Fuel

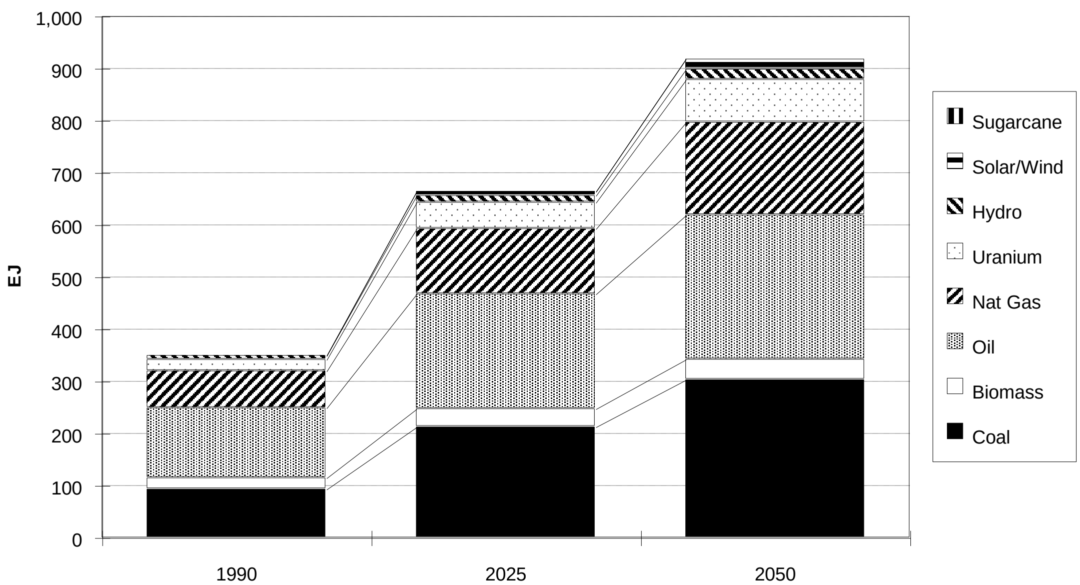


In the OECD regions, Eastern Europe, and FSU, household and agricultural energy use remain fairly constant, while most demand growth occurs in the transportation and services sectors. Significant growth also occurs in the industrial sector, especially in

Eastern Europe and FSU. In contrast, the developing regions experience significant growth in all sectors except agriculture. Of particular note is the rapid expansion of use in the industrial and services sectors in China+ and South and South East Asia.

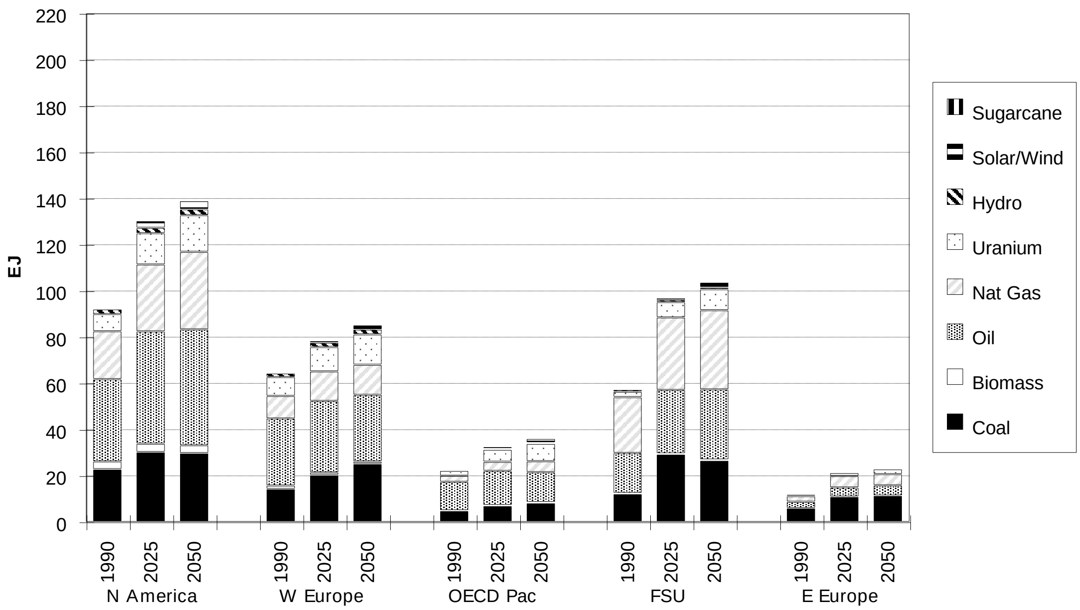
Global *primary* energy supply increase from 350 EJ to over 900 EJ over the scenario period (Figure 7). Primary supply includes final demand plus the energy lost in extraction, distribution and conversion to final fuels (e.g., electric power generation, petroleum refining, alcohol production, and charcoal making). Primary supply also accounts for the trade in energy commodities and net changes in stocks, and is equal to primary production plus net imports (defined as imports minus exports) plus stock changes. As such, it is a measure of the total primary energy resources needed in each region.

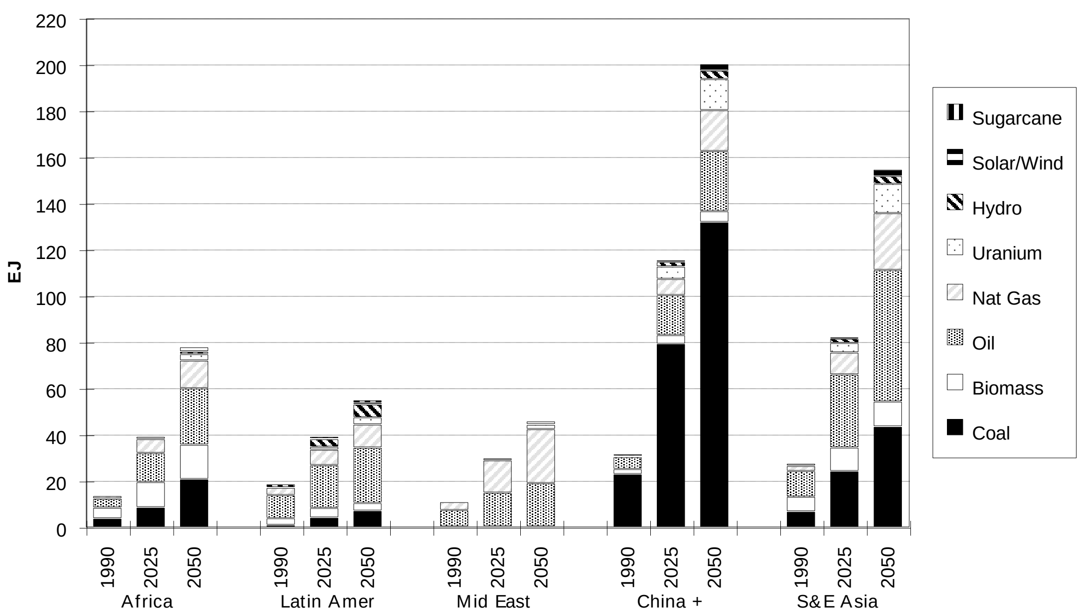
Figure 7 Global Primary Energy Supply



Fossil fuels continue to dominate, accounting for 82% of global primary energy supply in 2050 compared to 86% in 1990. However, there is a significant absolute expansion in renewable and nuclear primary energy supplies, by factors of 15 and 4, respectively. The regional patterns of primary energy supply are illustrated in Figure 8. By the end of the scenario period, China+ and South and South East Asia exceed North American total energy requirements. The changing regional mix of primary energy requirements is noteworthy. For example, coal grows rapidly in China+ in absolute terms but decreases as a share of total supply, while nuclear power (uranium) expands everywhere.

Figure 8 Primary Energy Supply





3.6. *Food and Agriculture*

Can we feed a growing world population, let alone provide more and better food to those who need it? This daunting question has stirred debate for over two centuries with little sign of resolution on the major issues involved. Have the dramatic agricultural productivity gains of the past three decades already over-stressed such basic resources as land and water so that they must soon tail off? Or, on the other hand, can we continue to bring new land into production, improve the efficiency of agricultural resource use, and raise crop and livestock productivity many-fold through better incentives for farmers and more science?

The point of departure of the conventional development food and agriculture scenario is the assumption of continuity in basic patterns -- gradual adjustments in diet patterns with rising incomes, gradual improvements in average yields, and progressive expansion of settlements and agricultural areas at the expense of forests and other land. As such the CDS represents a mid-range course between the pessimism which argues that the world has already overshot the population carrying capacity of the global agricultural system (Ehrlich, 1968), and the cornucopianism which sees no physical limits to food production (Simon, 1981). As we shall see, the scenario suggests good and bad news about the capacity to meet growing food demands. On the one hand, if anything like historic improvements in agriculture productivity persist, there will be enough food over the scenario time horizon to meet expanding demands. On the other hand, this encouraging conclusion could be undermined if institutional arrangements governing food supply and demand are not adjusted, if sustainable agricultural practices are not adopted and if land pressures and agrochemical pollution associated with expanded production are not ameliorated.

In the conventional development scenario food demand is driven by population growth (Section 3.3) and changes in per capita dietary standards as incomes increase. Regional average diets are defined by two broad indicators: total per capita daily calories and the fraction of these which comes from animal products. Consumption (and production) is also disaggregated into seven crop and three animal product groups.[9] Animal feed, industrial uses, seed requirements and processing losses are added to give total food demand.

Fish and other seafood contribute approximately 1% to global dietary calories but are important sources of protein and fats in some cultures. Total world catches of marine fish and shellfish have more than doubled in the past 30 years but have declined slightly from a peak of 85 million tonnes in 1989 with indications of stress or decline in major fishing zones (Brown et. al., 1994). Output of fresh water fish has grown rapidly in the same period to reach about 16% of total fish production.

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[9] The 10 food product groups are: cereals (except rice), rice, roots, pulses, non-tree oil crops, sugar crops, vegetables, tree and other perennial crops, meat and eggs, milk, and fish. For further details on the scenario, see Leach (1995).

The scenario assumes that the fraction of dietary intake from fish declines so that global fish demand increases from about 100 million tonnes to 135 million tonnes by 2050. The projected fish demand could be met by holding marine production at today's level while increasing production from other sources at one third of the historic rate. To make up this 35 % increase and any losses from marine catches due to over fishing, this would require the continued expansion of aquaculture production, now at about 15 million tonnes per year.

On the supply side, for each region and crop group future demand is matched by production plus net imports (i.e., production must equal demand plus net exports). Future production levels are driven mainly by improved crop yields but also in some regions by greater cropping intensity (number of crops per year) and increases or reductions both in total cultivated area and the share of farmland devoted to each crop group.

Following historic trends, dietary standards rise substantially in developing regions (and OECD-Pacific, which includes Japan) but at generally slower growth rates than in the past 30 years. In the other industrial regions, the main dietary indicators alter little so that, globally, dietary standards converge to a considerable extent (see Figures 9 and 10). Most regions continue to substitute higher-valued foods for cereal staples as incomes rise, though the gradual historic decline in the component of total consumption from animal products -- driven largely by health concerns -- is maintained in North America.

Putting these assumptions together, by 2050 global demand for cereals doubles in the scenario and for other crops and animal products it rises by factors of 2.3 and 2.4. These are substantial increases but, due to slower growth of population and per capita food intake, global crop requirements actually increase more slowly than in the past. With cereals, for example, global demand rises by 1.1% per year during 1990 to 2050, or less than half the average rate over 1960-1990. In some developing regions, however, rapid population growth combined with large dietary improvements leads to huge increases in total crop demand (see Figure 11). For example, in Africa demands for cereals and other crops increase by factors of 5.1 and 4.3 respectively; in the Middle East the equivalent figures are 6.1 and 4.9.

Figure 9 Diet changes: per capita daily calories

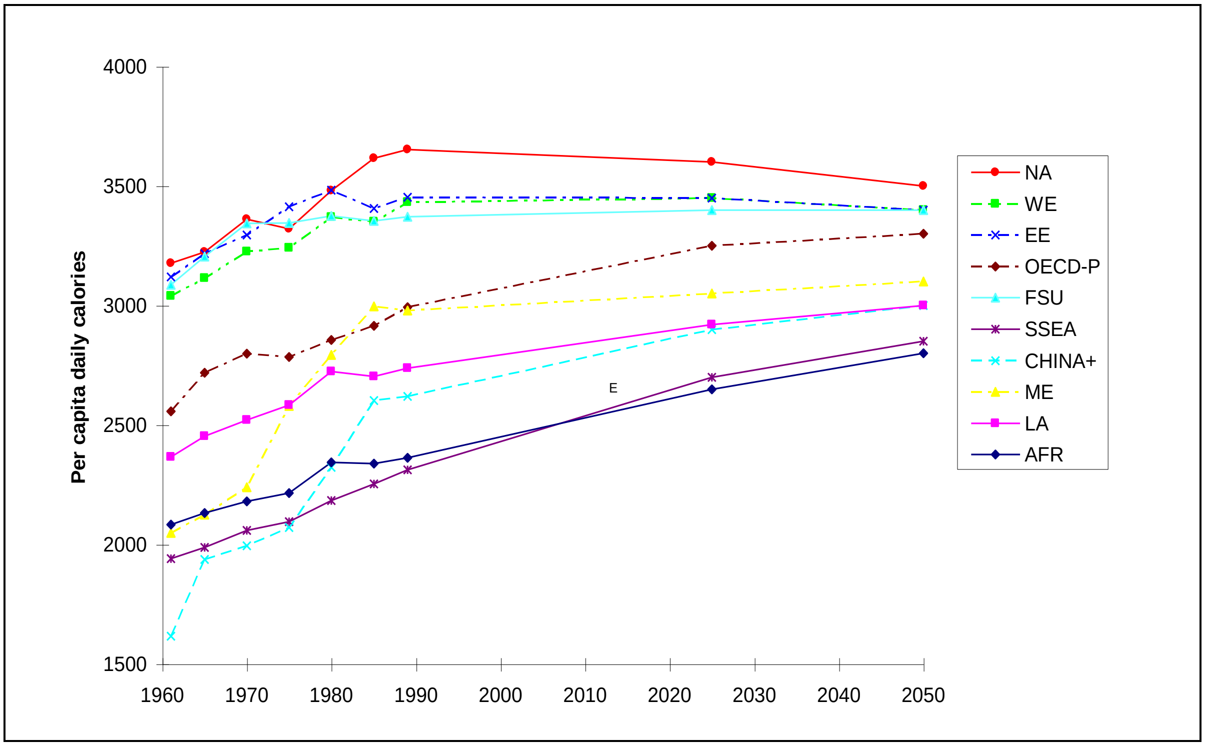


Figure 10 Diet changes: share of calories due to animal products

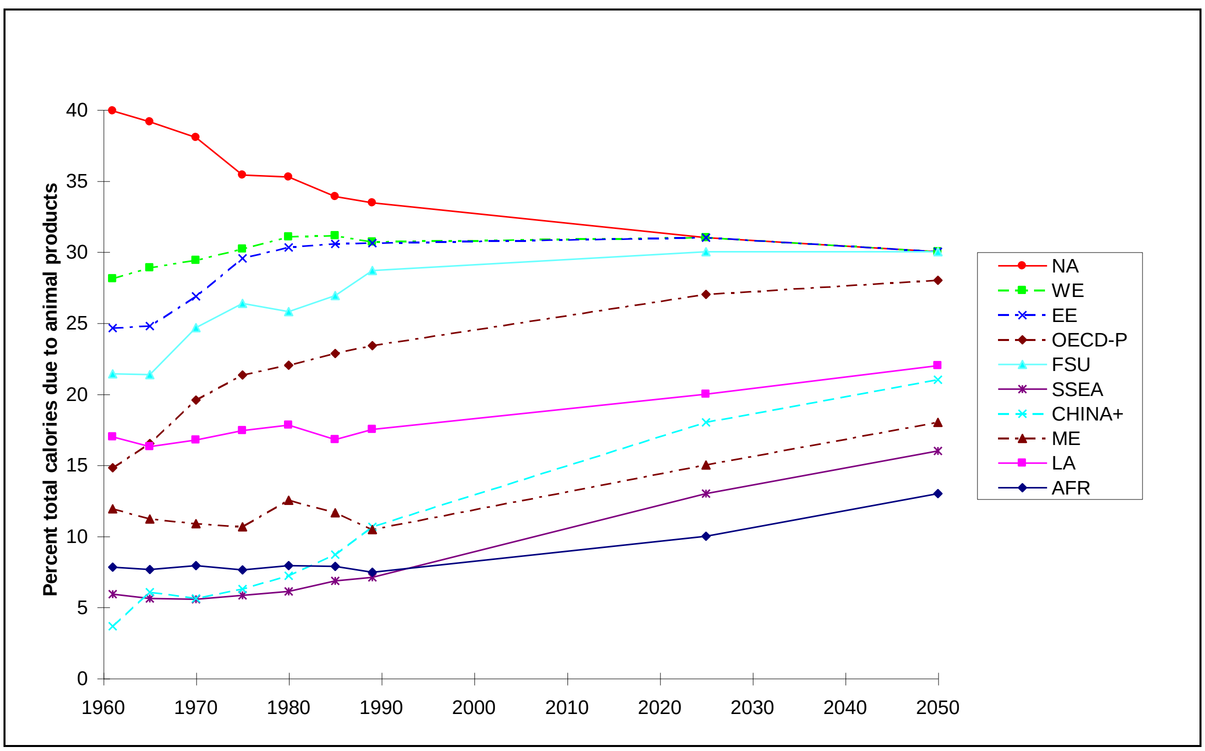
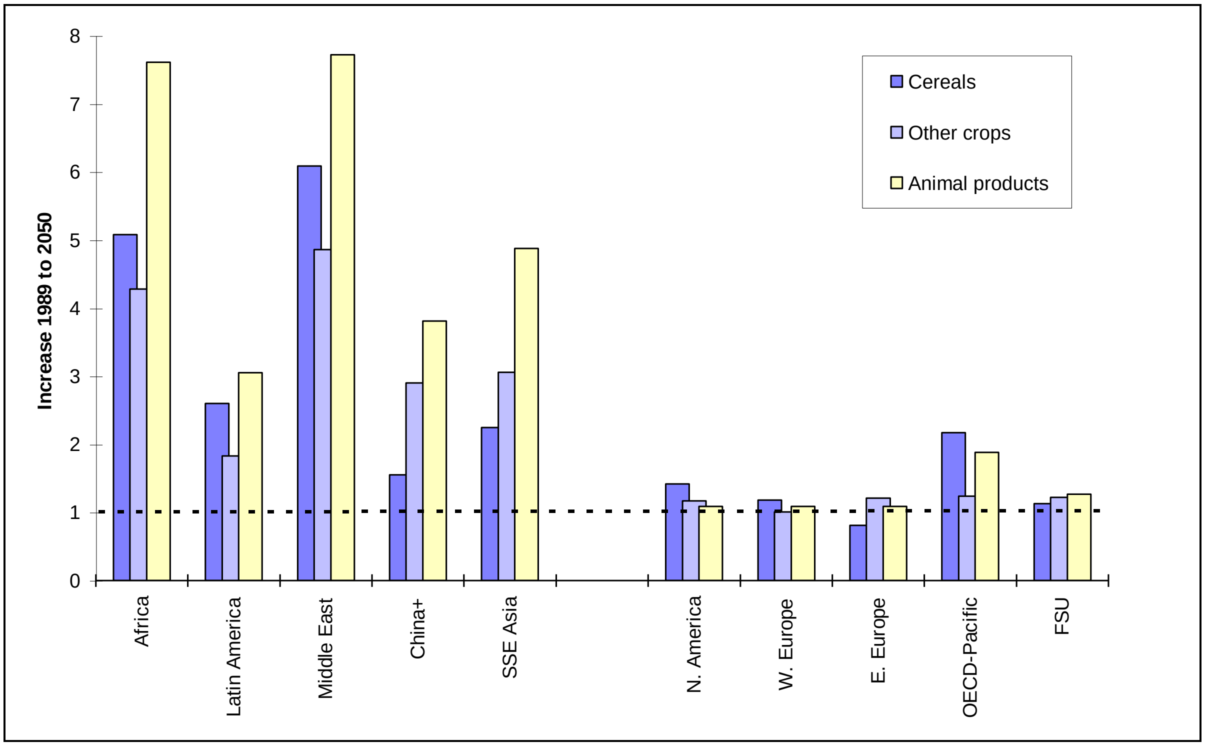


Figure 11 Total food demand in 2050 compared to 1989



Total demand includes animal feed, industrial uses and losses as well as human food

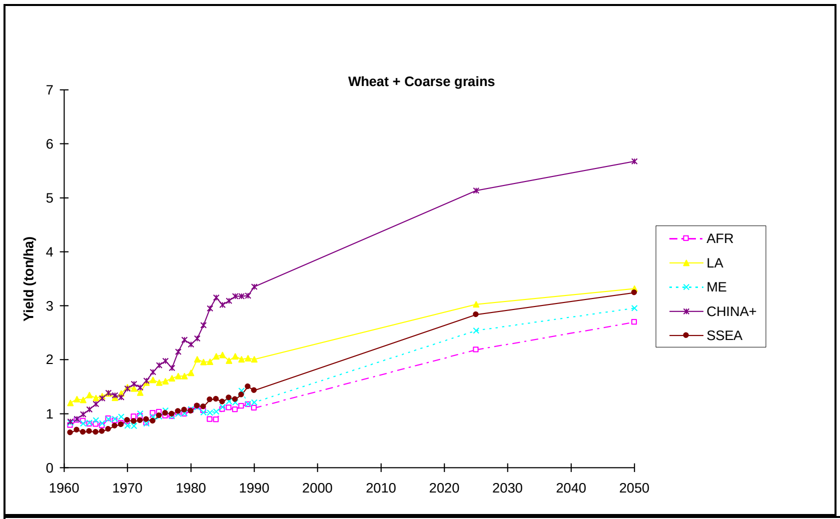
Increasing total cropland is one way of meeting these extra demands. However, in several developing regions little expansion is possible due to physical or technical constraints[10]. In the industrial regions over-production has led to policies to stabilize or reduce farm areas. Consequently, whereas cultivated land areas increase during 1989 to 2050 by 57% in Africa and 20% in Latin America they rise by only 2% to 7% in the other developing regions. In OECD-Pacific cropland area increases by 19% but falls by 3% to 5% in the other industrial regions. Within these totals, irrigated areas increase quite modestly by 15% to 25% in the developing regions and 11% to 19% in the rest of the world. Cropping intensities also increase, by close to 20% in the developing regions except the Middle East where the rise is 66% over today's very low level. In the industrial regions cropping intensity is unchanged in Europe (where it is now quite high) and increases by 10% elsewhere.

The remaining increases in regional food production are met by higher crop yields. Generally, these continue to grow at close to historic rates or those projected by FAO for the period 1990 - 2010 (FAO, 1993). However, regional yields in 2050 never exceed the highest national average yield found today. In some cases - notably in Africa -

[10] For developing regions the scenario analysis used data from FAO and IIASA on potential cultivated land (FAO, 1993; Fischer, 1994).

the scenario assumes that yield growth picks up following recent periods of stagnation or decline. The scenario yield assumptions for cereals are shown in Figures 12 and 13.

Figure 12 Yield assumptions: cereals excluding rice



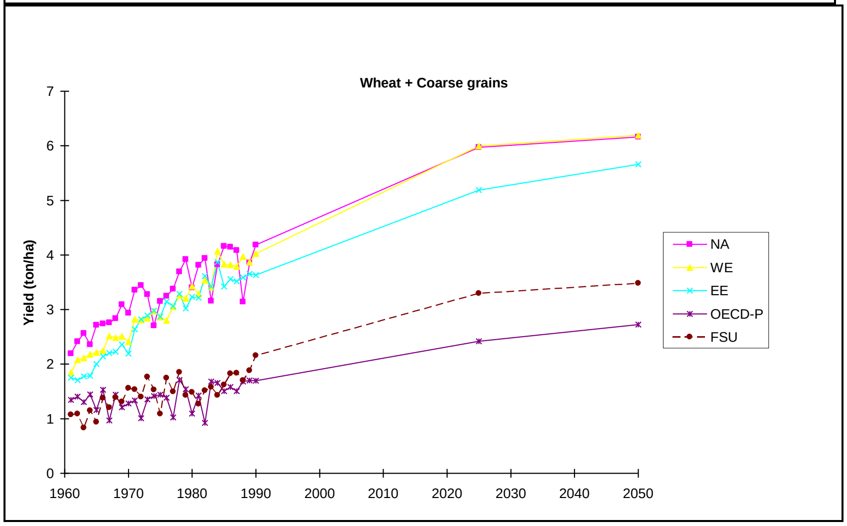
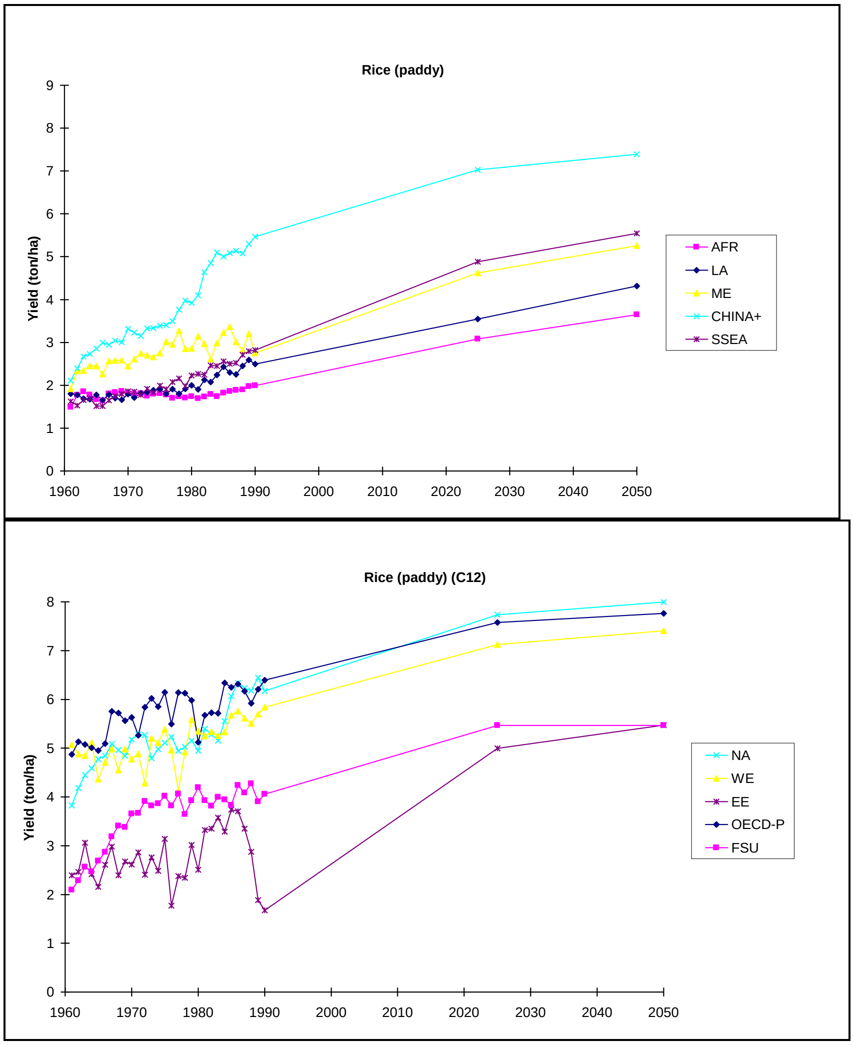


Figure 13 Yield assumptions: rice



Despite these fairly optimistic assumptions, cereal deficits and imports increase alarmingly in the most vulnerable regions, Africa and the Middle East, but also in OECD-Pacific. To make good these deficits, the other industrial regions have to increase greatly their export volumes. Similar but much less pronounced patterns apply to non-cereal crops. Crop self-sufficiency ratios, defined as domestic production divided by total requirements, the difference being the traded volume, are shown in Figures 14 and 15. The fact that the world's most developed regions, which are now trying to reduce food "over-production" (in the sense of lack of effective demand, not of global nutritional needs), must step up production again to help feed the rest of the world, is one of the most problematic aspect of this part of the whole conventional development scenario.

Figure 14 Self-sufficiency ratios: cereal crops

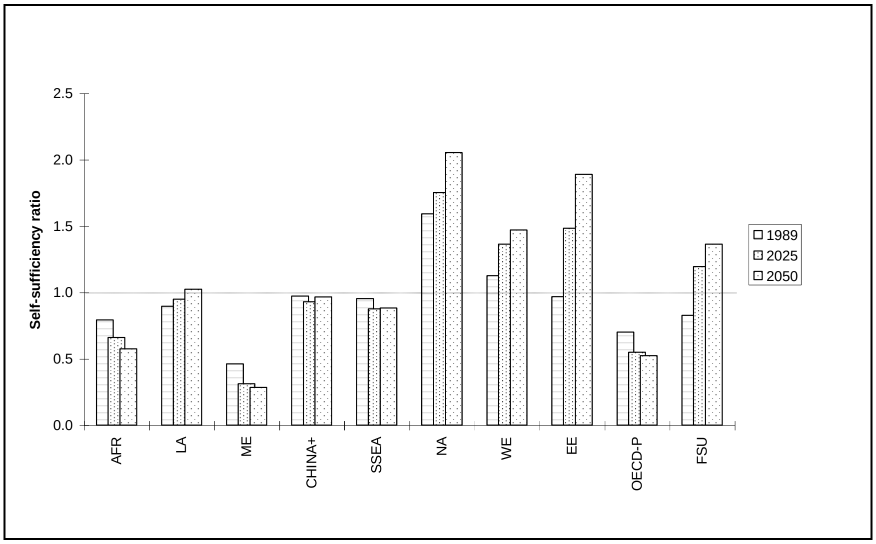
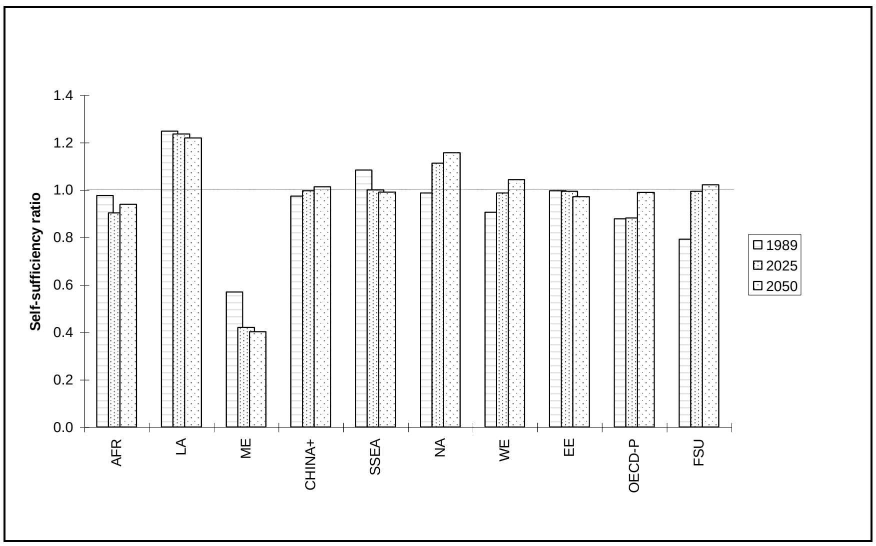


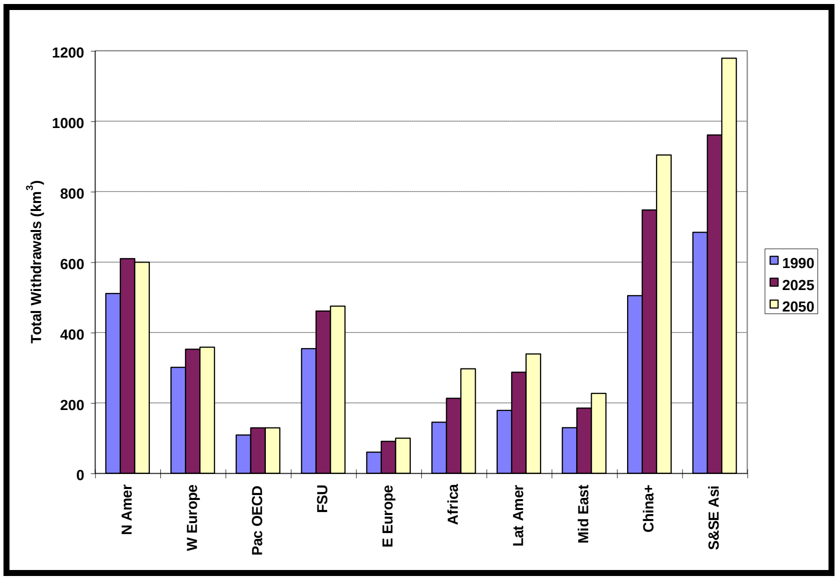
Figure 15 Self-sufficiency ratios: non-cereal crops



3.7. Fresh Water Requirements

Fresh water requirements increase at a much slower rate than economic output, by a factor of just over 1.5 over the period, from about 3000 km^3 to 4000 km^3 in 2025 and 4600 km^3 in 2050. The decrease in aggregate water intensity (water requirements per unit of GDP) is traced both to increasing water efficiency and gradual shifts to less water intensive economic activities. Withdrawals in the CDS are developed for each region for domestic, agricultural and industrial sectors.[11] These are summed to the total regional figures presented in Figure 16.

Figure 16 Total Water Withdrawals in the CDS



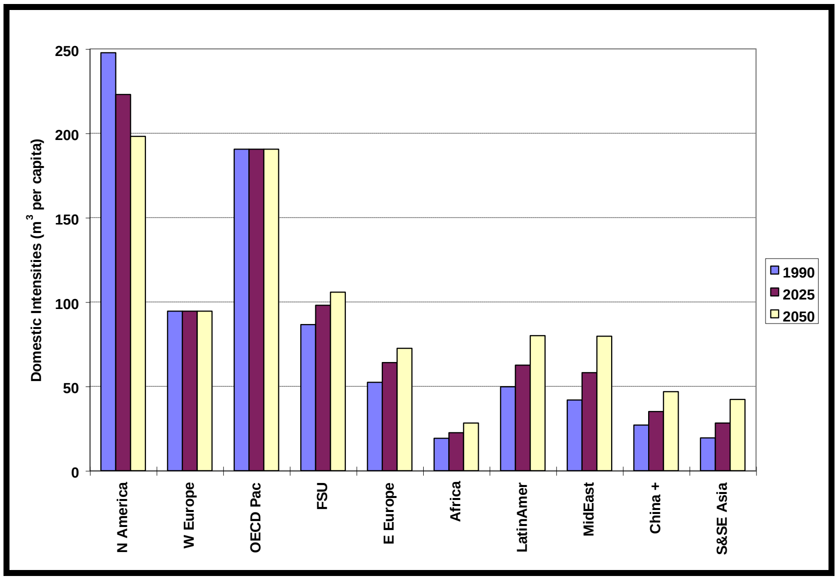
In the three OECD regions, historic growth in withdrawals slows considerably in the CDS. In fact, withdrawals in North America eventually decrease, while moderate growth occurs in Western Europe and OECD Pacific. In contrast, withdrawals in China + and South and East Asia nearly double over the period to satisfy the domestic needs of burgeoning populations, input requirements for manufacturing and energy production in rapidly growing economies, and irrigation requirements for the intensification of agriculture. By 2050, 45% of global withdrawals are projected to occur in China + and South and East Asia.

It is useful to look at water requirement trends by sector. Global data for the *domestic* sector includes water use in households and in the service sector. Water is used in households for consumption, toilets, dish washing, bathing, cleaning, and outdoor use (e.g., lawn watering, car washing, decorative uses). The service sector includes such water intensive establishments as restaurants, cleaners, hotels, and hospitals. Data limitations require that we aggregate over these diverse activities. Domestic water requirements are described as the product of two factors: population and water intensity,

[11] The water aspects of this report are based on Raskin et al. (1995), where technical details are presented.

defined as water use per person. Domestic water intensities in a given region reflect many factors, for example, income levels, water infrastructure development, technology and water availability. CDS values are presented in Figure 17, reflecting the effects of continued improvement in water use efficiency in OECD regions, and the growth of demands and the convergence of technologies elsewhere.

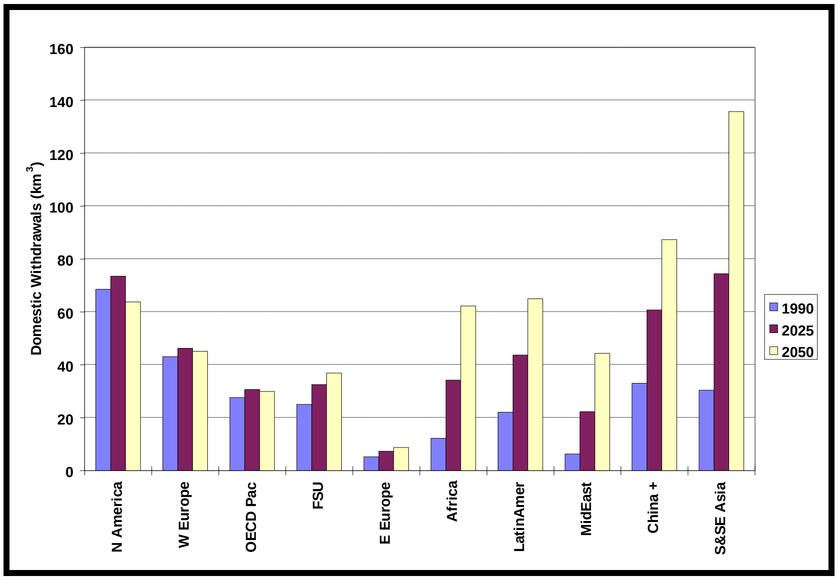
Figure 17 Domestic Intensities in the CDS



Source: Raskin et. al. (1995a).

Domestic water withdrawals are computed by multiplying these intensities by the population assumptions in the scenario.. The results are shown in Figure 18. Water use in the OECD regions changes little since population growth is slow and water intensities either increase or are steady; however, the other regions show large increases. Burgeoning populations and economies are projected to drive domestic withdrawals in South and Southeast Asia to 136 km^3 in 2050, almost five times the 1990 value, while in China+, withdrawals grow by almost a factor of three. Global domestic withdrawals reach 430 km^3 in 2025 and 580 km^3 in 2050, compared to 270 km^3 currently.

Figure 18 Domestic Withdrawals in the CDS

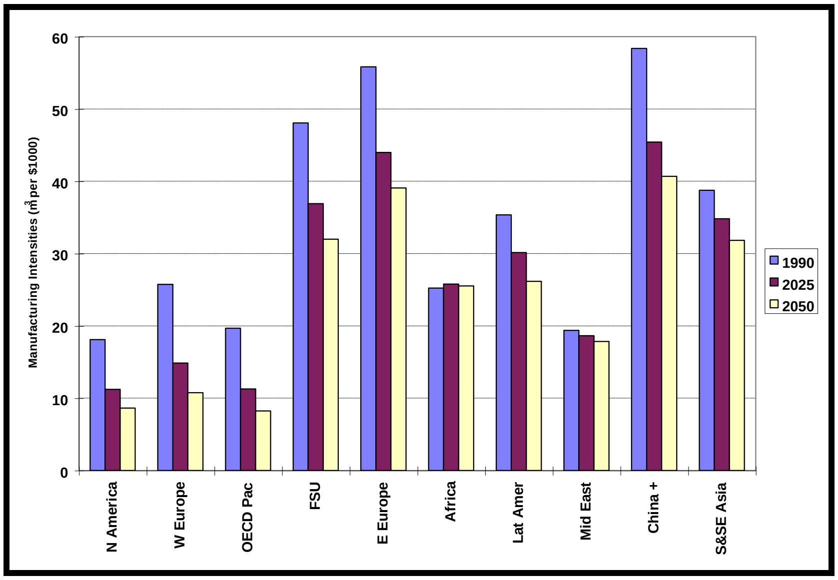


Source: 1990 withdrawals from various recent years from WRI (1994). Projected withdrawals as described in text.

Industry accounts for approximately 22% of current global fresh water withdrawals. In addition to standard industrial activities -- manufacturing, mining, quarrying, and construction -- *industry* data also include energy sector uses -- thermoelectric generation and petroleum refining. This broad grouping masks differing development and technological patterns across industrial subsectors and regions. In the scenario, manufacturing, refining, and thermoelectric generation are treated separately.

Water intensity trends depend on assumptions on use efficiency (e.g., degree of on-site water recycling), processes employed, and product mix. In the OECD regions, the rising share of the less water-intensive sectors in itself lowers aggregate manufacturing water intensity. Increasing efficiency and industrial growth are reflected in the CDS manufacturing intensities shown in Figure 19.

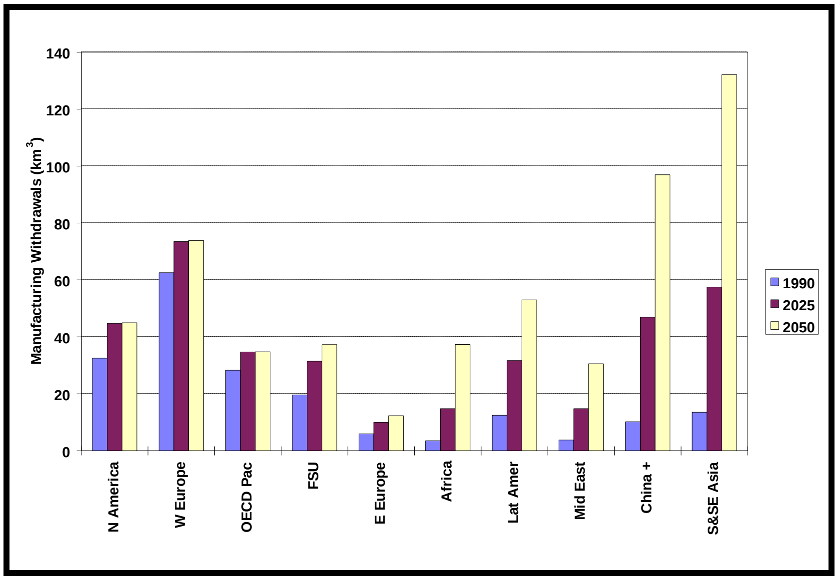
Figure 19   Manufacturing Water Intensities in the CDS



Source: Raskin et. al. (1995a)

Combining activity and intensity figures, we arrive at the manufacturing water withdrawal scenario shown in Figure 20. Globally, annual water withdrawals in the sector increase from 190 km^3 in 1990 to 550 km^3 per year by 2050. Regional variations are due to the interplay of region-specific assumptions about industrial scale, structure and intensity, as outlined above. The dramatic growth in developing regions is particularly striking. For example, the combined withdrawals of China + and South and East Asia rise to 230 km^3 per year by 2050 -- greater than the world total in 1990. These increases in manufacturing water withdrawals occur despite considerable decreases in water intensities during the scenario period.

Figure 20 Manufacturing Withdrawals in the CDS



Source: 1990 and projected withdrawals as described in text.

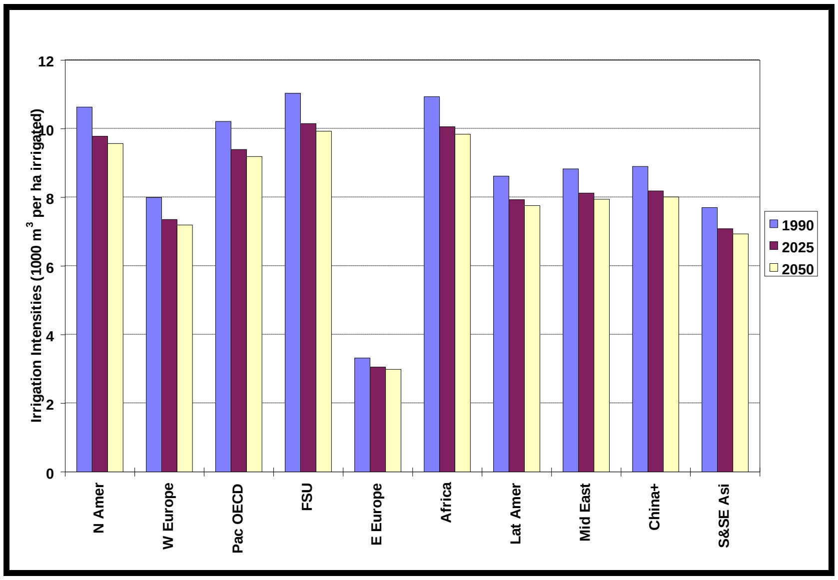
Nearly 70% of current global fresh water withdrawals are for agricultural applications primarily for irrigation. Irrigated agriculture contributes about one-third of global crop production (Kendall and Pimentel, 1994). Roughly 16% of the world's cultivated land is currently under irrigation, with yields typically much higher than for rainfed agriculture. For example, in the United States irrigated farming yields average about four times those of rainfed farms (Bajwa et. al., 1987).

Irrigation water intensity, defined as withdrawal per irrigated land area, depends on a number of interacting factors. These include the mix of crops under irrigation, the length of the growing season, land quality, local weather conditions, and irrigation methods. In the future, changes in these factors could either increase or decrease intensities. For example, as modern high yield crops substitute for more traditional varieties, water requirements generally increase. Withdrawal intensities would also increase if, as assumed in the CDS, cropping intensities increase as a result of reducing fallow times or increasing the average number of harvests per year. On the other hand, more efficient irrigation methods could substantially reduce water requirements.

Changes in irrigation methods are likely to be the dominant force in shaping future intensities, assuming that no significant alterations of hydrological patterns emerge from climatic changes. While the potential for more water efficient irrigation practices is significant, their implementation generally requires increased capital investments. Given the limited capital available for such investments, especially in developing countries, it is unlikely that the full technical potential will be achieved under conventional development assumptions. Moreover, intensity reductions will be partially offset by increased water requirements for higher yielding crops and increasing cropping intensities, as assumed in

the CDS (Leach, 1995). Combining these factors, we arrive at the CDS irrigation intensities displayed in Figure 21.

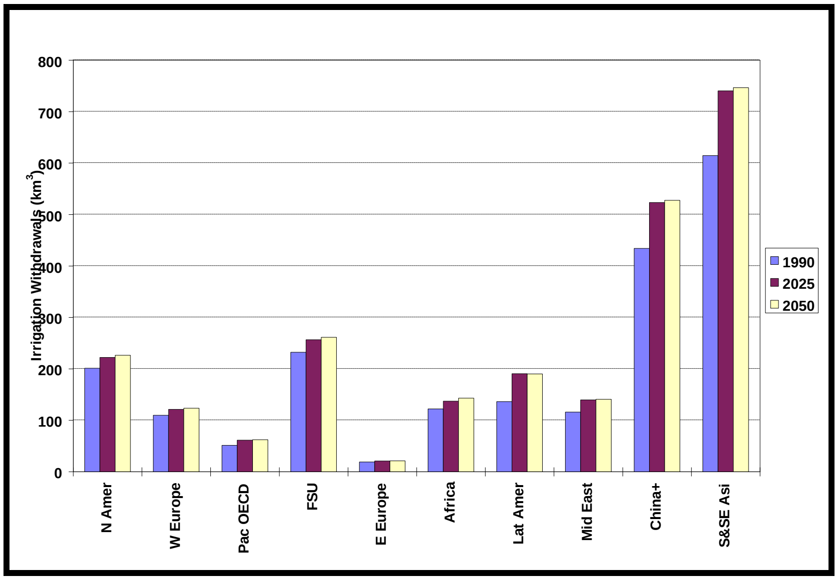
Figure 21 Irrigation Withdrawal Intensities in the CDS



Source: Raskin et. al. (1995a)

Combining these figures with the CDS assumptions on irrigation area expansion and intensities, we arrive at the irrigation water withdrawal scenario shown in Figure 22. Globally withdrawals increase about 20% by 2050. Withdrawals increase more slowly in the latter part of the scenario, because intensities are assumed to decrease more slowly and the area under irrigation grows more slowly. As discussed in Leach (1995), the area of irrigated land grows more slowly between 2025 and 2050 because most of the potentially irrigable land is assumed to be brought under irrigation by 2025. Water intensities decrease more slowly between 2025 and 2050 because the most inexpensive and straightforward improvements are assumed to take place by 2025, and further improvements are partially offset by increasing yields and cropping intensities.

Figure 22 Irrigation Water Withdrawals in the CDS



Source: 1990 withdrawals based on WRI (1994). Projected withdrawals as described in text.

3.8. Toxic and Hazardous Emissions

A wide variety of toxic and hazardous substances is used in the manufacture of industrial products. Nearly 100,000 industrial chemicals are now in commercial use worldwide, and this figure is increasing by 500 to 1000 each year. This increase has been driven in part by the availability of petroleum-derived by-products of an expanding oil industry, and in part by the increased role for complex chemicals in new and expanding technological contexts, such as agriculture, metal purification and metal plating, electronics, textiles and the food industry.

Some of these chemicals may not present significant threats to human health or to the environment, while others are known to represent specific toxicological and ecotoxicological impacts. However, there is insufficient scientific information even for a partial health assessment for about 90% of them (NAS, 1984). US legislation now requires larger companies to provide an annual inventory -- the Toxics Release Inventory -- of releases for some 300 toxic chemicals. These include toxic heavy metals (e.g., mercury, cadmium and lead) and a range of chlorinated organic compounds. Such substances pose particular threats in the environment on account of their toxicity, persistence, and tendency to "bioaccumulate" in living organisms, and through the food chain (Jackson and Taylor, 1992; Dethlefson et al., 1993).

The material and chemical flows underlying the modern industrial economy are immensely complicated and are not well-tracked and understood. Nevertheless, it is important in the context of a transition to sustainability to develop estimates of existing levels of emission of toxic and hazardous substances into the environment, to project

trends and to explore alternative scenarios for keeping emissions within acceptable risk levels.

With this aim in mind, the World Bank has devised an "Industrial Pollution Projection System" which uses the Toxics Release Inventory to provide lower bound toxics "emission factors" for many industries expressed as emissions per activity level (employment, value added, and output). Value added emission factors to air, water and land have been aggregated to major industrial sectors in Table 7.

Table 7 Toxic Emission Factors (tonnes per US$ billion value added)

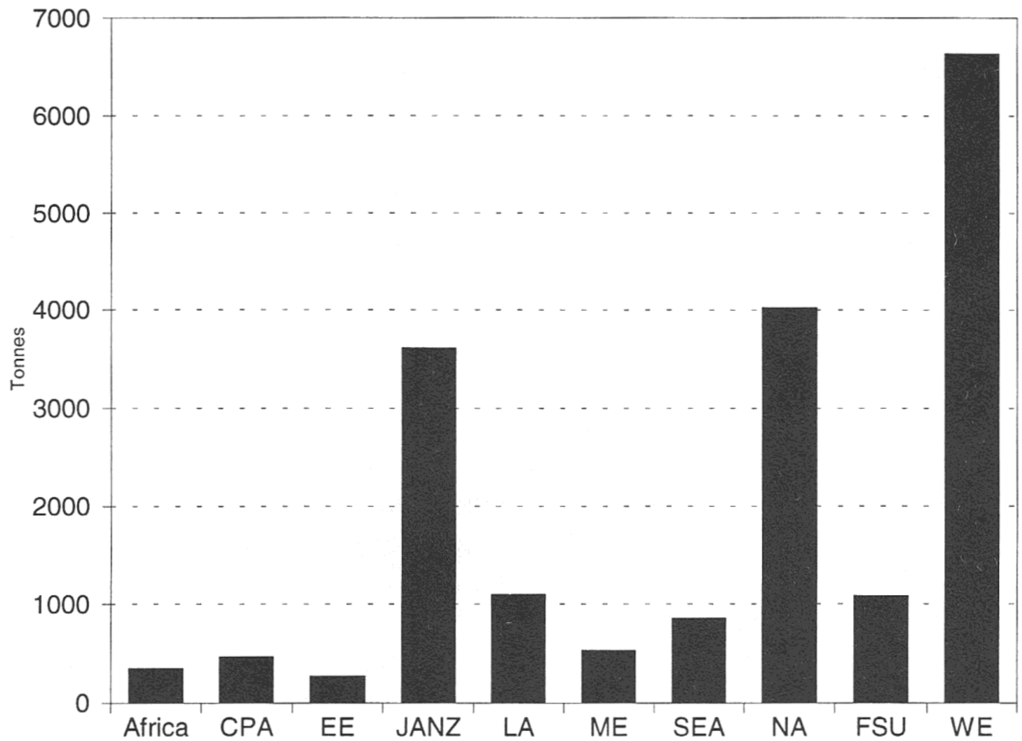
	Iron & Steel	**Nonferrous metals**	**Nonmetallic Minerals**	**Paper & Pulp**	**Chemicals**	**Others**
Air	1,027	4,331	316	1,399	2,005	547
Water	5,884	11,481	317	509	3,781	554
Land	365	168	11	281	317	20
Total	7,276	15,981	643	2,188	6,103	1,121

The table indicates that very high emissions per unit of industrial output are generated from the non-ferrous metals industry. High emission levels are also associated with the iron and steel industry and with the chemical industry. Other industrial sectors have considerably lower emission factors. Applying these emission factors to the industrial GDP assumptions of the CDS (see Section 3.4), it is straightforward to compute a "lower bound" estimate for global toxic emissions of 18.9 million tonnes. The breakdowns of these emissions by industrial subsector are shown in Figure 23. Note that the chemicals industry has the largest sectoral share (37%) .with metals industries also significant.

Figure 23 Lower bound toxic emissions by industrial subsector (1990)

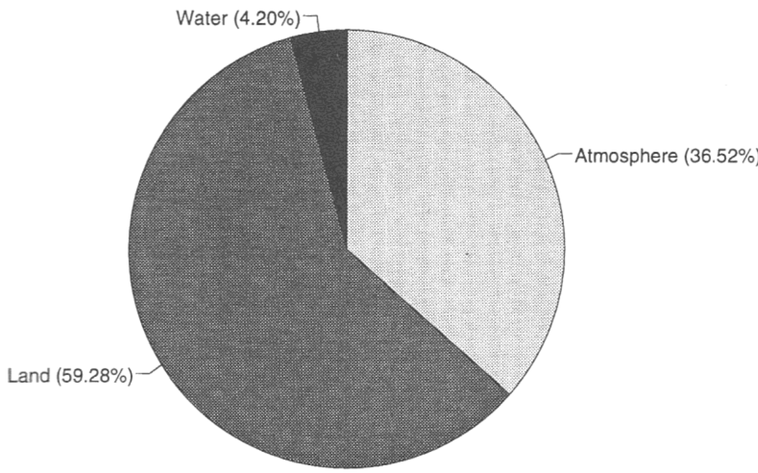
Emissions by region are presented in Figure 24. Not surprisingly, the developed world -- North America (NA), Western Europe (WE), and the Pacific OECD -- dominates the global toxic burden from manufacturing industry.

Figure 24 Lower bound toxic emissions by region (1990)



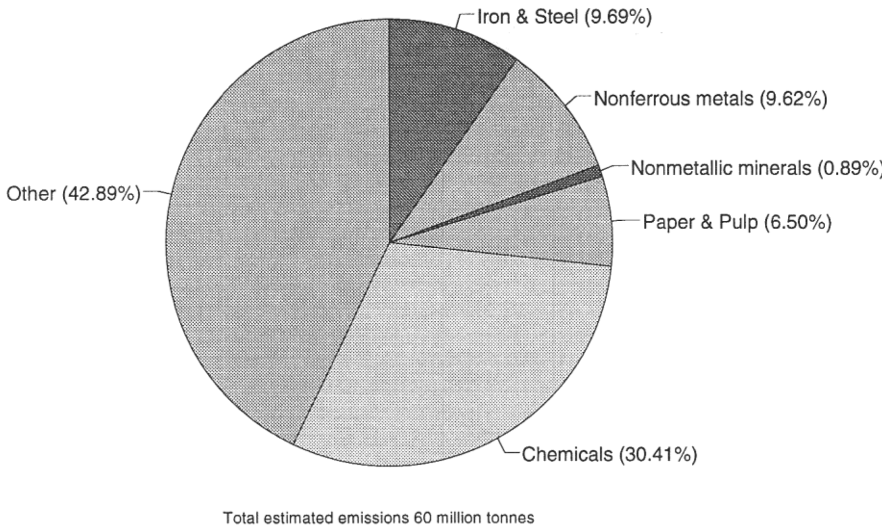
The fate of toxic emissions by environmental media is presented in Figure 25. Nearly 60% of emissions are to land, about 36% to the atmosphere, with aqueous environments receiving a relatively minor share of the total burden. Note that these proportions refer only to the *initial* partition of emissions into specific environmental media. The "ultimate" fate of emissions is determined by environmental transport and transfer mechanisms. In particular, atmospheric emissions will be subject to subsequent deposition both on land and into waters. Moreover, chemicals deposited on land may leach into water supplies. However, it is infeasible to compute the ultimate burden on specific environmental media which depends not only on transport and deposition, but also on metabolisation rates, sedimentation patterns, plant uptake, and so on.

Figure 25 Lower bound toxic emissions by emission medium (1990)



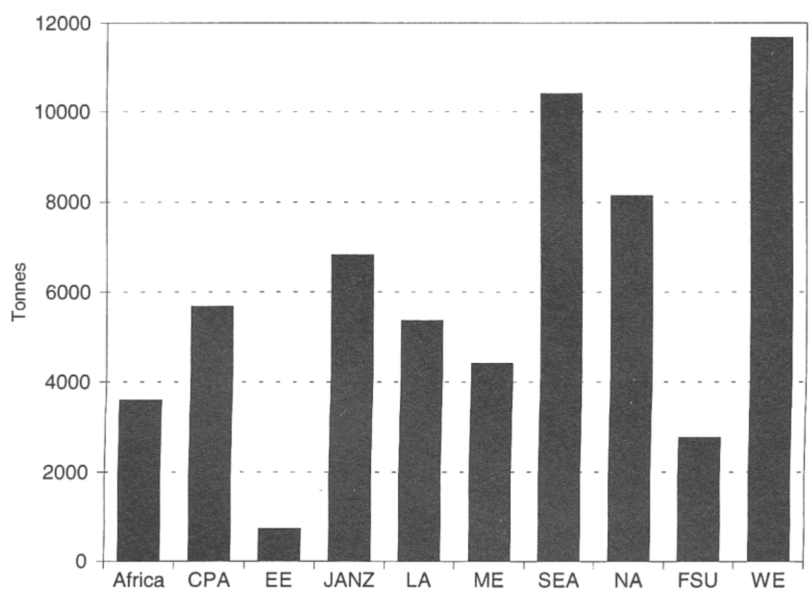
CDS projections of toxic emissions are driven by the economic assumptions described in Section 3.4. GDP growth is used to estimate lower bound values of toxic emissions to the year 2050. Total toxic emissions calculated on this basis amount to almost 60 million tonnes, or three times greater than current levels. The sectoral composition of this burden (Figure 26) is similar to the current allocation. The chemicals sector is still important, as are the metals sectors. However a greater proportion of the burden now comes from "other" sectors. This effect is associated with the reduction in material intensity of use of conventional materials such as iron and steel which is assumed in the scenario.

Figure 26 Lower bound toxic emissions by sector (2050)



The future regional distribution of impacts differs somewhat from the current patterns shown in Figure 24. As shown in Figure 27, the newly industrializing nations -- particularly in South and South East Asia -- begin to contribute significantly to the global toxic burden in the scenario.

Figure 27 Lower bound toxic emissions by region (2050)



These estimates should be regarded as illustrative only. A number of limitations concerning the quality of the data, and the applicability of the accounting methodology,

need to be highlighted. In the first place, the data have been drawn from a single country (the US) and the degree of validity of extrapolation on a global basis is not clear. Although the pattern of technological development in other OECD regions may not be vastly dissimilar to the US example, the extension of these emission factors to less developed economies may introduce significant inaccuracies. In general, the effect will be to underestimate actual emissions in less developed regions, because technological efficiencies and environmental controls are likely to be inferior (Jackson and MacGillivray, 1995a).

The application of the emission factors to estimate future levels also introduces uncertainties. Some "natural" improvements are likely to be associated with economic development, as more investment capital is mobilized for newer and more efficient technologies with lower emission levels. This would imply that the use of current US emission factors for developing regions becomes more realistic in future years. On the other hand, future total toxic emissions may still be underestimated because projected levels of economic development in the non-OECD region are significantly less than present OECD levels.

4. What's Wrong with the Conventional Picture?

The Conventional Development Scenario is an orthodox vision of development assuming the global progression of the values and growth dynamics of western industrialized civilization. The guiding principles of the scenario are *evolution, convergence, and integration.* Demographic, socio-economic and technological patterns gradually evolve without significant surprises, radical technological innovations, or fundamental policy changes. Developing and transitional regions are assumed to converge gradually toward OECD consumption and production practices. Finally, in the CDS, the world becomes progressively more integrated both economically and culturally.

The conventional development scenario has not been introduced in order to divine a future which is either probable or desirable. As we shall see, conventional development as characterized here would likely be knocked far off course by the stresses it would impose on environmental, resource and institutional systems.

Furthermore, the continuity assumption of the scenario is deeply problematic, since history suggests that the future will likely hold big surprises. However, the CDS does offer a useful cognitive aid for understanding the constraints on business-as-usual development, and a reference for exploring the timing and scale of policy measures for catalyzing alternative development scenarios.

4.1. Fossil Fuels

The requirements for fossil fuel resources in the scenario increase substantially over the scenario period in all regions. The increase is most pronounced in the developing regions. These demands would place great pressure on oil and gas

resources.[12] At CDS usage levels, currently estimated global proved oil reserves are depleted around 2025 and additional oil reserves are depleted around 2035. To a lesser extent, natural gas requirements in the scenario also push against resource constraints with proved global reserves depleted around 2050, and additional reserves about 60% exhausted by 2050. On the other hand, coal remains abundant throughout the scenario period.

The CDS requirements are inconsistent with current estimates of reserves. Either very large additional conventional resources would need to be discovered to meet the requirements of the CDS, or a significant shift to unconventional sources for liquid and gaseous fuels would be required. New discoveries of oil and gas resources large enough to increase resource expectations significantly are unlikely (Masters et al., 1990). In the past, some analysts considered only "proved reserves" in evaluating oil sufficiency, leading to overly dire concerns about impending oil shortages since most additional reserves are eventually reclassified as proved. Exaggerated claims of scarcity contribute inevitably to the opposite pitfall of insufficient concern for resource limits. However, estimates of the *sum* of proved and additional reserves has, in fact, been relatively constant over recent decades.[13]

Unconventional options include tar sands and shale oil, as well as gas from coal beds, and very-low-permeability reservoirs. Today, such sources play a minor role in international petroleum budgets, well under one percent of production. Significant technological and infrastructural hurdles must be overcome for these options to become cost-competitive in large quantities. Furthermore, low oil prices over the last ten years have interrupted the research, development and investment momentum for these unconventional fuel forms. Whether these sources can play a major role at economically acceptable costs remains uncertain. Furthermore, a transition to unconventional sources of oil and gas would carry environmental penalties of the same magnitude as conventional sources, including carbon dioxide emissions which *exceed* conventional fuels.

Some energy models, particularly those developed between the time of the OPEC oil embargo of 1973 to the mid-1980s, when unconventional petroleum sources were given heavy policy attention, assume a smooth global transition from conventional to

[12] Mineral statistics are generally organized into the categories of *resources*, which are estimates of all physical deposits, and *reserves*, that proportion of resources which is considered economically exploitable. The latter is in turn composed of *proved reserves*, which can be commercially exploited under today's technological and economic conditions and estimated *additional reserves recoverable*, which are estimated to be recoverable (with reasonable certainty) given current geological and engineering information. Reserve estimates in this study are drawn from WEC (1992).

[13] By the 1960s petroleum geologists began to report estimates of ultimate world oil resources around 270 billion tonnes, and ultimate world natural gas resources around 10,000 trillion cubic feet (Masters et. al., 1990). These estimates of ultimate resources (proved reserves, additional reserves *and* resources previously extracted) have remained remarkably constant over time, and are within 5% of current estimates.

non-conventional fossil fuels.[14] While this cannot be ruled out, the economic, technological and environmental uncertainties suggest that it would be imprudent to rely on a transition on such an immense scale. There are alternatives -- less energy intensive activity patterns, maximum efficiency in end-use equipment, heavy reliance on renewable energy, substituting hydrogen, ethanol and methanol for liquid petroleum -- but they take us beyond the conventional development paradigm.

Beyond global supply and demand relationships, the geographical distribution of fossil fuel resources has important geopolitical implications. Remaining oil reserves are heavily concentrated in the Middle East (43%), Latin America (35%) and China+ (8%).[15] Natural gas reserves are heavily concentrated in the FSU (34%), the Middle East (30%), and Latin America (9%). By the year 2025 in the CDS, North America, Europe, OECD-Pacific, and the FSU have become largely dependent on imports, China+ is self reliant, and Africa meets half of its requirements through imports. Global oil exporters are the Middle East and Latin America, which export about 90 and 80 EJ, respectively, of a total global oil requirement of 220 EJ.

These patterns have profound ramifications for international politics, global economic stability (the oil shocks of the 1970s suggest the potential vulnerabilities to oil price manipulations), and international security (the 1991 Gulf war is a recent case where oil politics contributed to international conflict). The conventional development path would progressively intensify the role of the politics of oil in world affairs, with the attendant risks of economic vulnerability, heightened international tensions, and war.

In addition to constraints on the oil resource itself, there can be financial and institutional hurdles to the expansion of production capacity. Some oil-rich countries face substantial problems in the mobilization of capital. Foreign investment participation is delimited so oil-sector investments must compete with other national priorities for scarce capital resources (IEA, 1994). Also, in certain areas, such as parts of the Former Soviet Union, infrastructure is insufficently maintained and secure for reliable oil production. If capacity expansion does not keep pace with growing demand requirements, current excess capacity would decrease. This would provide the basis for strengthened cooperation among OPEC countries, thereby increasing the likelihood of a resurgence of the cartel’s capability for manipulating oil supplies and prices.

Expanded combustion of fossil fuels is implicated in a number of environmental impacts (Holdren, 1992). In addition to increased risk of global climate change (discussed in the next subsection), we touch on four of the more significant impacts here. First, oil spills associated with international petroleum trade currently add about 50,000

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[14] For example, the IPCC scenarios were generated using the Atmospheric Stabilization Framework (ASF), and the ASF uses a version of the Edmonds-Reilly model which has this feature (Edmonds and Reilly, 1985).

[15] Again, these figures reflect *both* proved and additional reserves. Considering proved reserves alone, the Middle East share rises to 65%.

tonnes of oil per year to oceans. Second, about 90% of the sulfur dioxide emissions and perhaps half of nitrogen oxides (NO_x), the precursors to acid rain, are related to energy combustion. Third, energy is a significant source of some toxic heavy metal releases accounting for most of the lead added to the environment, and significant contributions to anthropogenic loads of mercury (20%) and cadmium (13%). Finally, nearly half of particulate and non-methane hydrocarbon emissions are from energy.

Actions are being taken today to mitigate many of these environmental risks, through emissions controls and fuel choices, e.g., away from leaded gas and high sulfur coal. It is possible that the impacts can be adequately controlled in an evolutionary way without impeding the growth assumptions of the CDS. On the other hand, rapid urbanization will aggravate ground level air pollution and the sheer volume of combustion will counteract measures to control unit emissions. Furthermore, the *cumulative* effects of environmental loads such as toxification of soils and acidification are not well understood. The questions for the future are the adequacy of current environmental measures in light of expanded fossil fuel use, the degree to which appropriate actions will be adopted across regions, and the acceptability of the associated costs. Avoiding these uncertainties is an additional benefit of alternative energy scenarios which rely less heavily on fossil fuel combustion.

4.2. Climate Change

There is scientific consensus that human activity is increasing the atmospheric concentrations of the so-called greenhouse gases, and that this carries risks of climate warming, altered hydrological patterns, and sea-level rise (IPCC, 1991, 1995). There is significant uncertainty and debate regarding the likely level of biospheric response to continued anthropogenic emissions and to the ultimate human and ecosystem impacts. Nevertheless, because of the scale of the risks, climate change has become a major item on the international agenda. The issue is being addressed both through national programs and an international treaty process, the Framework Convention on Climate Change, officially convened in 1994 and likely to take many years as it touches on fundamental questions of development, and North-South interactions.

Stabilization of atmospheric concentrations of greenhouse gases at current levels would require immediate reductions in emissions from human activities of over 60% (IPCC, 1990). While such deep reductions of greenhouse gas emissions would minimize the threats to human and ecological systems associated with climate change, there is no realistic near term way to achieve these levels because of the momentum built into current practices and the recalcitrance of political positions. Current negotiations aim at the far more modest first step where the richer countries strive to keep their greenhouse gas emissions in the year 2000 at 1990 levels. Meanwhile, poorer countries argue incisively that the lion's share of the responsibility for reduction lies with the rich countries that have caused most of the problem. Developing countries will aim to link their participation in decreasing greenhouse gas emissions, or providing biomass sinks for

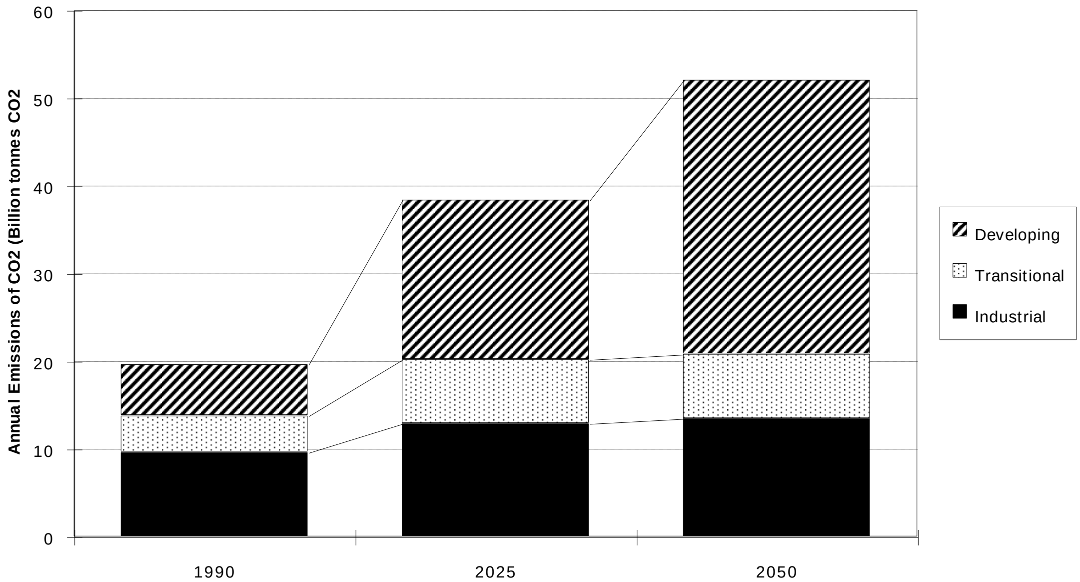
carbon, to the transfer of technology and greater development assistance from the North. Reaching a new global bargain encompassing these issues will test the capacity of international cooperation.

If strict climate stabilization is not a possibility, it may be asked whether there are levels of climate change which can be tolerated without overly severe impacts. The Advisory Group on Greenhouse Gases (AGGG), organized by the World Meteorological Organization, the International Council of Scientific Unions, and the United Nations Environment Program, addressed this question by developing estimates of thresholds of climate risk (Rijsberman and Swart, 1990). To protect vulnerable ecosystems, the AGGG recommended limiting the rate of sea level rise to between 20 and 50 mm per decade, and limiting the rate of change in global mean temperature to no more than 0.1°C per decade, with a maximum cumulative warming of 1.0 to 2.0°C from pre-industrial levels. More rapid sea level change would threaten natural wetlands, coral reefs, and island nations, and significantly increase the severity of storm damage to society and to ecosystems. Faster temperature change could result in rapid, unpredictable, and non-linear responses of the climatic system that could lead to extensive disruption of natural and socio-economic patterns.

Remaining within these targets would require reducing carbon dioxide emissions to 50% of their 1985 levels by the middle of the next century (IPCC, 1990). Carbon dioxide is the most important anthropogenic greenhouse gas, accounting for 55% of the change in radiative forcing between 1980 and 1990 (IPCC, 1990). Further, the production and use of energy is the dominant source of carbon dioxide emissions, accounting for 85% of current global emissions (Subak et al., 1992).

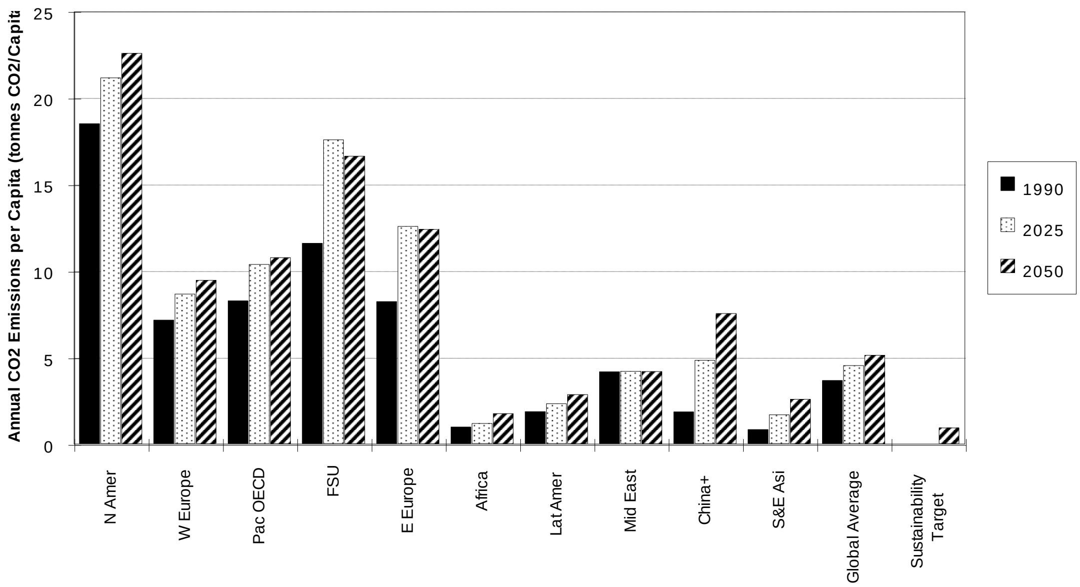
In sharp contrast to the AGGG sustainability guidelines, energy-related carbon dioxide emissions in the CDS *increase* rapidly. As shown in Figure 28, annual global carbon emissions from energy in 2025 are about double current levels and in 2050 are almost triple. Developing region emissions increase by a factor of 5 over the scenario period. The gap between these trends and the requirements for remaining within the risk thresholds noted above, suggests the huge scale of emission abatement levels that must be part of alternative scenarios for achieving sustainability.

Figure 28 Energy Related Carbon Dioxide Emissions in the CDS



The structure of emissions across regions is also notable. Despite the relatively rapid growth in total annual emissions in developing regions, emissions per capita in those areas remain significantly below industrialized countries. The relative emissions per capita are shown in Figure 29. Emissions per capita are often mentioned as a reasonable measure of inter-country equity in setting abatement targets. The figure shows how far from this goal the world is today, and would continue to be under conventional development assumptions. The figure also contrasts the average emissions per capita in the scenario in 2050 with the average level to achieve the sustainability target. Indeed, emissions per capita exceed the sustainability target in each region. In the industrialized countries, an immense change would be required in per capita emissions -- and thus in energy practices -- to reach averages within the global targets.

Figure 29 Energy Related Carbon Dioxide Emissions per Capita in the CDS



4.3. Nuclear Expansion: Uncertainties and Risks

The share of nuclear energy in the global mix grows slowly from about 6% in 1990 to 9% in 2050. Since total energy requirements increase by a factor of 2.5 over this period, nuclear generating capacity increases by almost a factor of four, from 330 GW [16] in 1990 to 1200 GW in 2050. This corresponds to an average *net* annual increment of twelve 1 GW facilities to 2025, and nineteen per year after that, mostly in developing regions. New construction would need to exceed these figures in order to make up for the retirement of older units which have design lifetimes of 30 to 40 years, requiring a dramatic rebound of the industry.

Installed nuclear capacity grew to the current levels after 1960 through rapid annual increases in the 1970s and 1980s. However, installed capacity may not grow further in the near term, and, in fact, is likely to decrease (Brown, 1994). This is due to compound effects of a reduction in new construction starts from a peak of over 30 GW/year globally in the mid-1970s to less than 3 GW/year in the 1990s, and the retirement of existing facilities as the first generation of nuclear reactors ages. Reversal of this pattern will require overcoming substantial barriers which can be classified into four categories: cost, safety, radioactive waste disposal, and, perhaps the most daunting of all, security.

[16] A gigawatt (GW) equals one thousand megawatts, roughly the size of a large nuclear power plant.

Once claimed to be "too cheap to meter", nuclear power in practice has proved in many countries to be too expensive to build due to construction overruns, stronger regulatory requirements (often to ensure greater levels of safety), and high operating costs (Flavin, 1984). A renaissance of nuclear power on the scale of the CDS will require less costly, more modular and more reliable technologies.

Since the early years of the era of nuclear power, the accident risk at nuclear facilities has been sharply debated (U.S. Nuclear Regulatory Commission, 1975; von Hippel, 1977; Lovins and Price, 1975). Whatever the inherent risks, the public reaction to several major accidents -- especially the incidents at Three Mile Island in the USA and Chernobyl in the FSU -- had a chilling effect on the industry. The expansion of nuclear power at CDS levels would entail, among other things, overcoming safety concerns by demonstrating the increased reliability of advanced designs. However, the long range security of nuclear power is compromised by the risk that a major accident in the future could prompt, as in the past, calls for moratoria on nuclear power.

The annual generation of highly radioactive and long-lived waste from spent fuel from commercial nuclear plants was about 10,000 tonnes in 1990 (Adamantiades, 1991). Cumulative global generation in the CDS would grow from approximately 80,000 tonnes in 1990 to about 1.4 million tonnes by the year 2050.[17] Adding to this total would be the high level radioactive wastes generated from decommissioning and dismantling power plants at the end of their useful life. Designing and siting a permanent repository for such toxic and long-lived waste is exceedingly difficult, due to technical uncertainties and local resistance. The need to monitor and contain the waste for tens of thousands of years is a legacy from the nuclear era to the future that is difficult to assess in terms of health and safety risks, or economic costs. Nevertheless, it is a legacy that would seem to violate the fundamental tenet of sustainability that current needs and aspirations be met without unduly burdening generations to come.

Nuclear power programs increase the danger of the proliferation of nuclear weapons by creating greater access to reactor grade fuel[18] and to plutonium in spent fuel. The linkage between civilian and military nuclear programs has been brought into sharp focus by recent concerns that North Korea, Iraq, and other countries are engaged in the reprocessing of spent fuel to recover weapons grade plutonium. Furthermore, the appearance of plutonium from Russia on the European black market raises the specter

[17]The waste includes plutonium 239, one of the most toxic substances known, with a half-life of some 20,000 years. The original concept was a closed nuclear fuel-cycle in which plutonium and uranium would be recovered, separated and reused. Most countries do not have functioning reprocessing facilities so that the open cycle once-through technology has become the norm. As a consequence, high-level radioactive waste is accumulating in on-site storage pools at nuclear plant sites. While removing much of the plutonium and uranium in spent fuel, reprocessing increases the volume of high level radioactive waste.

[18] In June 1994, the United States Secretary of Energy revealed detailed information on a test explosion in 1962 that relied on reactor-grade plutonium, rather than the normal weapons grade material.

that terrorists or aggressive states will have increasing access to the raw material for nuclear weapons (Whitney, 1994). The global output of plutonium from nuclear power reactors is already about 50 tonnes of plutonium per year, enough for nearly 1000 Nagasaki-size bombs.

The danger of diversion to weapons fabrication is mitigated today by the highly radioactive character of spent fuel from conventional open cycle reactors, since a reprocessing facility would be required to separate the plutonium. But the once-through technology relies on virgin uranium resources that will become increasingly scarce at the levels of nuclear generation envisioned in the conventional energy picture. To achieve the scenario goals, spent fuel would need to be reprocessed and plutonium recovered for reuse in conjunction with breeder reactors.[19] Though the United States abandoned reprocessing during the Carter administration to decrease the spread of plutonium, other countries -- Britain, France and Russia -- are already generating far more plutonium than can be used, leaving stockpiles of over 100 tonnes of plutonium around the world (Sanger, 1994). Already a major market for European plutonium, Japan has plans to construct its own reprocessing facilities, further raising risks of diversion.

The scenario would increase such international flows and bring all regions of the world into the plutonium economy. The tremendous increase in the flow of plutonium envisioned in the conventional development scenario, the expansion of the number of global regions involved in plutonium commerce, the difficulties in enforcing safeguards on a global basis, and the ease by which nuclear weapons can be fashioned from separated plutonium, imply a strong and intrinsic link between the nuclear power option and nuclear weapons proliferation. In an era of regional conflict, extremist social movements, and unstable regimes, the risk of weapons proliferation places a high cost -- and high uncertainty -- on expansion of the nuclear power option at the levels envisioned in the conventional development scenario.

4.4. Hydro Power: Construction Disturbances

In the CDS, annual hydroelectric power production increases by a factor of 2.5 overall, and a factor of 5 in developing regions. From the perspective of economic and technical potential, the level of expansion in the scenario is feasible. Moreover, as an indigenous and renewable energy resource, hydropower offers the benefits of reducing fuel import dependency and air pollution relative to fossil fuel-fired generating options. These benefits are conditional, however. The renewability of hydropower is only approximate since reservoir siltification gradually erodes the resource potential, and the

[19] A full shift to breeder reactors by 2025, which generate fissionable materials as a by-product and use uranium 60 times more efficiently than open cycle reactors, would address the resource constraint in the scenario. However, in addition to the proliferation risks discussed in the text, breeder reactors pose the risks of higher cost and increased complexity relative to conventional nuclear designs. The only functioning breeder reactor, the Superphenix in France, has had severe operating difficulties. The expansion of breeder reactors to meet the nuclear power requirements of the CDS cannot be considered likely.

contribution of hydropower to self-reliant development is compromised insofar as the financing and construction of these capital intensive facilities depend on external hard currency loans and foreign contractors.

Beyond issues of engineering feasibility and cost-competitiveness, the construction of large-scale hydroelectric facilities can significantly disrupt local communities and ecosystems. The environmental and social impacts of hydroelectric plants include disturbance of the spawning grounds of migratory fish; flooding of natural habitats, farmlands, and communities; displacement of populations; alteration of local hydrological patterns; and risks of catastrophic flooding from dam failure. With many of the best sites already exploited, it seems likely that opposition will increase as facilities are proposed that carry increased costs --economic, environmental and social. At the least, CDS levels of hydropower expansion will require greater sensitivity by development authorities to environmental and social costs in project evaluation, and more active involvement by affected communities in the siting process.

4.5. Traditional Fuels and the Rural Environment

The so-called traditional fuels -- wood, charcoal, animal dung and agricultural waste -- are widely used in developing countries, particularly for domestic cooking. Rural households generally rely on fuelwood and, as this resource becomes more scarce, on dung and wastes. In some countries, many urban households use wood-derived charcoal, a compact and transportable fuel with cost advantages over direct use of fuelwood in certain areas where markets are far from forest and other wood resources.

Historically, industrializing countries have undergone an *energy transition* from traditional fuels to modern fuels and electricity due to a combination of higher income, increased urbanization, and the spread of modern infrastructures and values to rural areas. The CDS reflects this process as household energy patterns in developing regions converge toward OECD levels with economic growth.

In the conventional view, traditional biomass use will continue at high levels in rural areas and amongst the swelling ranks of the poorest in urban areas for many decades in Africa, and perhaps to a lesser extent in Latin America and Asia. As a general matter, the energy transition in developing regions will be slowed by higher energy prices than faced by the industrialized countries at comparable levels of development and income. Additionally, rural areas and low-income urban areas are likely to have continued difficulties accessing modern fuels, while end-use equipment costs are high relative to incomes. Modern fuels in rural areas carry additional costs related to up-country transport and poor infrastructure. By contrast, biomass fuel collection costs are perceived as low due to lack of employment, status and cash incomes for women (typically collectors of traditional fuels).

Finally, the decrease of the absolute number of poor people, the primary users of biomass for energy in developing countries, may be slow despite income growth. This number may be expressed as the product of two factors, total population and the fraction of the population who are poor. There are contrary effects here. Population increases swell the number of poor, all else equal, while increases in average incomes tend to decrease the number. The result is indeterminate since it depends on the shape of income distribution curves and how these change in the future. If income distribution becomes more skewed in the course of development, with growing disparities between the rich and poor in a given region, the actual numbers of people at low income levels could stay constant or increase. For example, in India average GDP per capita grew by almost a third between 1973 and 1988, while the absolute population in poverty decreased only slightly and remains at over 300 million (Repetto, 1994).

The attendant issues of resource sufficiency, rural economic development and environmental stress would remain as well (O'Keefe et al., 1984; Leach and Mearns, 1988; Munslow et al., 1988). The character of the fuelwood problem is a complex matter, made more opaque by the lack of good data on consumption, collection, and the resource base. Nevertheless, there are known to be many areas of fuelwood shortage today. The lack of adequate wood sources is primarily due to land-use conversions in which standing stocks of trees are degraded, and further exacerbated by fuelwood demands. Indicators of shortage include increasing wood collection distances by rural householders (generally women and children), the substitution of animal dung and agricultural waste fuels for fuelwood, and actions by rural people either to use wood more efficiently or plant trees. The nature of the response to fuelwood shortage in a given area depends on local culture, traditions, and institutions.

Though rarely the primary cause, fuelwood exploitation beyond the limits of available renewable yields contributes to environmental stress in rural areas. Incremental loss of standing trees can increase runoff and erosion, and threaten habitats. When dung and agricultural waste fuels are substituted, soil nutrients and structure can be degraded. Furthermore, by continuing to occupying a substantial share of household labor budgets, fuelwood scarcity contributes to the perpetuation of poverty in rural households, with its deleterious demographic, social, and environmental implications for sustainability.

Generalities about the character of the problem of rural resources and the environment are perilous in light of the variation across local conditions. The broad-brush conventional energy development scenario can only suggest that wood requirements will remain high while, absent policies to foster a major rural energy transition, supplies will remain constrained, particularly as agriculture and settlement areas further expand with population and economic growth. The rural energy and environment issue must remain a priority on the agenda for a sustainable energy future.

4.6. Water Stress

In the CDS, global water withdrawals rise from 3,000 km^3/year to 4,600 km^3/year, about eleven percent of the average annual runoff of 41,000 km^3. Taken alone, these figures would indicate that human claims on freshwater would remain modest relative to available renewable resources. For several reasons, however, the sufficiency of freshwater is more problematic than might appear from global comparisons of resources and requirements.

First, most of the annual runoff is in the form of floods, leaving only about one-third, or 14,000 km^3 per year, as a steady supply (L'vovitch, 1974). Flood control measures, especially reservoir construction, can increase this figure by storing water during high flow periods for use during dry seasons. There are 30,000 reservoirs in the world today, with a total filled capacity of 6,000 km^3 and covering an area of about 800,000 km^2 (WRI, 1990). In the discussion of hydropower, we have already suggested the rising costs and uncertainties of incremental reservoir expansion.

Second, sustainable water use requires that adequate flows be maintained for the protection of river, lake, and wetland ecosystems. In addition, such in-stream human uses of river and lake water as recreation, navigation, and hydropower require the preservation of minimum flows. Water quality goals place further constraints on water availability. Water *quantity* and *quality* issues are closely linked as minimal river flow levels are required to dilute polluted waters to acceptable levels.

Third, global averages mask the spatial and temporal variance of freshwater resource and requirement patterns. There is great variation in the spatial distribution of water resources. In many catchment areas, water is plentiful and demands are modest, while in others water is very scarce, and already restraining development and degrading ecosystems. Moreover, fluctuations in rainfall patterns in many areas produce a cycle of droughts and floods, with significant seasonal and annual variations. Episodic water scarcity occurs even where time-averaged resources appear adequate. If human-induced climate change occurs, there is the further potential for long-range alterations in local hydrological patterns (IPCC, 1990).

The myriad natural and human uses of fresh water are linked by the unitary character of the water cycle. The use and misuse of water in one location can have far-flung effects, altering downstream resources, affecting the reliability of water flows, and degrading water quality and aquatic ecosystems. The reliability of the entire global hydrological cycle would be undermined if significant global warming results from the continued emissions of greenhouse gases from human activities. Climate change has the potential of perilously altering precipitation patterns, increasing the incidence and severity of droughts and floods, and causing intrusion of salt water in coastal areas.

As the competition for limited resources increases with expanding water use, water quality often deteriorates and ecosystem maintenance is compromised. In the absence of policies to address these tensions, water competition can evolve into discord between groups dependent on the same resources. Conflicts can arise between human and environmental needs, with the latter often the loser. Furthermore, inadequate or degraded water is a matter of life and death in developing regions where perhaps 25,000 people die daily from water-related diseases (UNEP, 1991).

The fundamental tenet of sustainability is that a non-degraded environmental and resource base be preserved for future generations. Three dimensions of water sustainability have been alluded to: human requirements, water security, and ecosystem maintenance. A sustainable water system would be robust, meeting human and ecosystem requirements in a manner that is resilient against fluctuations, risks, and surprises.

As a crude measure of water stress, we introduce the use-to-resource ratio, defined as the ratio of water use to renewable water resources. [20] End-use efficiencies, population, climate, and the level of industrial and agricultural development are factored in through their effect on use patterns. It is difficult to establish theoretical values linking the use-to-resource ratio to the levels of water sufficiency. However, a country which withdraws a large fraction of its renewable resources is likely to encounter water scarcity. Compatibility with long-term sustainability would require that most water is returned after use at acceptable quality levels, that groundwater stocks are not mined, that *in-situ* uses are not undermined, and that there is enough storage in the system to weather hydrological variability due to climate, or human alteration of imported water flows by upstream countries.

The aggregation of river catchments into national ratios also complicates the situation. In Egypt, the national water picture is, in essence, the story of a single river system, the Nile basin. A use-to-resource ratio of 97% clearly reflects the water stress in that country. However, in a multiple basin country like the United States, the relatively low ratio of 19% suggests overall water surplus, while masking water shortages in arid western regions of the country.

Countries where the current ratio approaches 100% are certainly hard pressed for water resources. Still, many countries where the ratio is less than 100% are still at risk of local water scarcity due to variability of the ratio over spatial subregions and/or temporal scarcity due to hydrological fluctuations. Also, in many countries the distributions of

[20] Water *use* refers here to withdrawals. The ratio of water *consumption* to renewable water resources would also provide useful insight, but country and regional data on consumption are not available. In applying the use-to-resource ratio, care must be given in situations where withdrawals are heavily for non-consumptive use such as power plant cooling where a relatively small fraction of withdrawals is consumed. In these cases, the use-to-resource ratio may exaggerate the pressure on water resources.

resources and requirements are not well matched, with some resources located far from demand centers. Inaccessible resources may not be available at reasonable cost, thus diminishing the maximum obtainable use-to-resource ratio.

An examination of the current use-to-resource values across countries suggests that threshold levels are extremely site-specific. Instream ecosystem requirements can place practical limits on the use-to-resource ratio, while minimum flows may also be needed for wastewater assimilation. Moreover, in countries with growing water demands, some reserves are required for growth. Nevertheless, some indicative thresholds have been proposed. Balcerski suggested that European countries with ratios above 20% would find water issues significantly affecting the total economy of the country, while countries with ratios below 5%, would find water issues solvable without serious problems (Falkenmark and Lindh, 1976). Gleick (1993) lists countries with ratios above 33% in which potential shortages could arise due to decreased supply or increased demand.

For the purposes of our analysis, we consider a ratio of 25% as indicative of *water stress*, depending on the specific country conditions. Instead of defining firm cutoff points, we simply recognize that, as the use-to-resource ratio increases, countries will generally experience greater water stress and scarcity. Based on this criterion countries currently facing water quantity problems are listed in Table 8.[21]

[21] The five now independent Central Asian republics facing severe water stress (Raskin et. al., 1992) are not among these since they are included as part of the Former Soviet Union in the analysis.

Table 8 Current Water Constraints Based on the Use-to-resource Index

Country	Index (%)	Condition
Kuwait	prob high	Scarcity
Libya	374	^
United Arab Emirates	300	|
Saudi Arabia	164	|
Yemen	136	|
Egypt	97	|
Israel	86	|
Belgium	72	|
Tunisia	53	|
Afghanistan	52	|
Korea Rep	44	|
Iraq	43	|
Spain	41	|
Jordan	41	|
Madagascar	41	|
Iran	39	|
Morocco	36	|
Pakistan	33	|
Singapore	32	|
Germany	31	|
Italy	30	|
South Africa	29	|
Poland	26	Stress

Source: Withdrawal and resource figures based on WRI (1994).

We next consider the adequacy of water resources in the CDS-- assuming infrastructure development -- to provide growing and diverse water services for economic activity, for people, for water quality maintenance, for ecosystem preservation, and for in-stream uses. Beyond this biophyscial aspect of sustainability there is an additional dimension: the economic capacity of countries to develop the infrastructure required to mobilize water resources. Today, many countries have abundant resources, while some of their citizens suffer from inadequate access to water for basic health and sanitation needs.

The regional trends in the CDS are shown in Table 9. The use-to-resource ratio increases for the Middle East from 58% in 1990 to 101% in 2050, for Eastern Europe from 41% in 1990 to 67% in 2050, and for China+ from 14% in 1990 to 26% in 2050. In the other regions, one again sees an intensification of current pressures on the water resource base. When reviewing the trends in regional use-to-resource ratios, it is

important to keep in mind that aggregating to the regional level masks significant differences in water resources and use across subregions and countries. Thus, while at the country level a use-to-resource ratio of 25% would be indicative of water stress, at the regional level a much lower ratio should be used.

Table 9 Use-to-resource Ratio in the CDS (%)

Region	1990	2025	2050
Africa	4	6	8
China +	14	21	26
Eastern Europe	41	61	67
Former Soviet Union	8	11	11
Latin America	2	3	3
Middle East	58	83	101
North America	9	11	11
OECD-Pacific	8	9	10
South and East Asia	7	10	13
Western Europe	14	16	17
World	7	10	11

We have seen that perhaps 23 countries are facing generalized water stress today, with far more facing subnational water sufficiency problems based on the criteria of use-to-resource ratios exceeding 25%. If the regional growth patterns in water withdrawals, as depicted in Figure 16, were applied to the countries within each region, then the number of countries experiencing generalized water stress by 2050 would increase by more than 50%. More importantly, emerging water problems would be intensified due to increased pressures for water within water-pressed subnational river basins of countries which in aggregate appear to have a water surplus.

The Conventional Development Scenario has focused on the adequacy of water resources to meet increasing withdrawal requirements. In addition to considering trends in *off-stream* water demands, an assessment of changing water requirements needs to consider requirements for competing *in-stream* services. There are three categories of such services. First, direct uses include the maintenance of reliable water flows for hydroelectric facilities, navigation and recreation. For example, in the CDS, annual hydroelectric power production increases by a factor of five in developing regions (Raskin and Margolis, 1995). Second, water systems are relied on for the assimilation of human waste products and pollution. And third, sufficient water resources are essential for supplying ecological services in which fresh water resources provide life support systems, nutrient cycling functions, and habitats. To the degree that demands increase for these various non-consumptive in-stream water services along with expanded water withdrawal requirements for production and domestic uses, future water constraints may be more profound then suggested by a focus on withdrawals alone.

4.7. Food, Agriculture and Land Resources

The population and economic growth assumptions of the Conventional Development Scenario imply significant alterations in the use of land. Settled areas expand significantly with the growth in housing and services, commerce and industry, roads and infrastructure -- collectively referred to here as the built environment. Cultivated lands expand to compensate for agriculture land converted to the built environment and lost to degradation, and to meet the net increase required to meet growing food demands, as discussed in Section 3.6. These increases are met by converting forests and other land types, which therefore must decrease in the scenario.

These changes will exert severe stresses on ecosystems which are now little affected by human pressures, such as wetlands and forests, as well as wildlife parks and other kinds of protected land. They will also bite heavily into agricultural land resources, particularly as the built environment expands into the belts of farmland which normally surround and support human settlements.

Adding to these problems are the environmental threats to land and other resources arising from the growth of agriculture itself. To feed larger populations with better diets, crop production in the conventional development scenario has to double by 2050 but has to increase nearly 3-fold in the developing world as a whole and 5-fold or more in Africa and the Middle East. Partly because of other pressures on land and shortages of undeveloped land which is good enough to farm, most of this huge production growth has to come not from expanding cultivated land but from greater crop yields as a result of more intensive land use, more irrigation, and more fertilizers. World-wide, cultivated land expands by only 10% between 1990 and 2050. As a result, per capita farmland is squeezed tightly by population pressures, falling from 0.20 to 0.11 hectare in the developing regions as a whole, compared to 0.55 and 0.48 hectare in the developed regions.

This degree of intensification carries high risks of further degrading already over-stressed land, water and other natural resources (McCalla,1995). The daunting challenge is therefore not only to double global food production on much the same land base as today but to do so sustainably while maintaining, and hopefully improving, vital land, water, fisheries, forests and other natural resources. Few doubt that this challenge is immense and the risks of failure appreciable. As one World Bank report has put it: "The interaction between population growth, the environment and agricultural intensification raises the most compelling and most controversial issues currently facing developing countries" (Lele and Stone, 1989).

Soil erosion and other forms of land degradation are generally agreed to present the most serious set of risks, although opinions differ widely on the scale, nature and causes of these problems. According to one authoritative source (CGIAR, 1994) globally about 2,000 million hectare of soils have become "degraded" due to human action since

1945 -- an alarming annual rate of 40 million hectare or 1% of the world's agricultural and pasture area. Lack of terraces on steep slopes, failure to replace nutrients removed in crops and crop residues, and excessive irrigation or drainage did most of the damage to arable land, while overgrazing has been the main problem on rangelands. Brown (1984) estimated that global soil erosion was 23 billion tons per year, or 0.7% of the total soil inventory. At this rate (compounded) half the world's soils would be lost in a century. A more recent estimate puts the annual soil loss at treble this rate, or 75 billion tons, mostly from agricultural land (Myers, 1993).

Africa in particular, with its ancient, heavily-leached, nutrient-deficient and easily erodible soils, is thought to face severe and growing problems of land degradation and increasing aridity which threaten to undermine its present agricultural base (Yates and Kiss, 1992), let alone any large expansion of its crop and pasture lands. One major survey estimated that 72% of Africa's arable land and 31% of its pasture land are already degraded (Oldeman et al., 1992); another that 50% of the farmland and up to 80% of the pasture area shows signs of degradation (Cleaver, 1993).

Most of this degradation acts to reduce plant productivity so that farmers must put more into the land to get the same out of it, or must switch to new crop and livestock production systems. More extreme is soil damage so severe that once-productive land has to be abandoned more or less permanently. Estimates for such losses include 7 million hectare per year (Lampe, 1994); 10-11 million hectare per year (Kendall and Pimentel, 1994); at least 10 million hectare per year including losses to urbanization and roads, etc. (Pimentel et al., 1992); and 12 million hectare per year "destroyed" and abandoned because of nonsustainable farming practices (Lal and Stewart, 1990).

Such estimates are, it must be said, widely criticized as uncertain or exaggerated. For one thing, the basic data are poor. Soil loss measurements on the same field by different teams can vary 100-fold or more (Seckler, 1987), and on the same small watershed by three to four orders of magnitude (Seckler, 1987; Stocking, 1993). Extrapolation of soil losses from field measurements to large watershed or continental scales is likely to exaggerate 100-fold or more (Stocking, 1995). The complex relationships between soil changes and declines in land productivity are also "beset by enormous uncertainties and errors" (Blaikie and Brookfield, 1987). Equally serious is the frequent selective misuse of these poor data for political or propaganda reasons. It is therefore hardly surprising that large-scale estimates of soil and land degradation have been called uncertain, contentious and disputed (Mortimore, 1993); that some authors state baldly that on the large-scale rates of soil erosion are simply not known (Seckler, 1987, Johnson & Lewis, 1995); and that the 1977 UN Conference on Desertification declared that "Statistics [on soil erosion and deforestation] are seldom in the right form, are hard to come by and even harder to believe, let alone interpret" (cited in Blaikie, 1985). However, none of these critics denies that soil erosion and land degradation are real threats to sustainability and that corrective measures are urgently needed.

As a "worst case" working hypothesis we might assume that productive cropland is being lost to severe degradation and the built environment at a global rate of some 10 million hectare annually. This is just over twice the recent rate of cropland expansion, which averaged 4.4 million hectare per year globally during 1961-89 (FAO, 1993). In the future this disparity could be as much as five-fold. In the CDS scenario global cropland expansion slows to 2.5 million ha/year (almost entirely in developing regions but with large regional variations). Assuming that "permanent" land losses continue at 10 million ha/year, then world-wide some 12.5 million hectare of new cultivable land will have to be cleared each year just to provide for the assumed cropland expansion. Additional new land will be required to replace losses of pasture land to degradation, the built environment and cropland as well as providing for net pasture area expansion.

As in the past, this large-scale conversion of new land to human use carries serious risks for human societies and the environment. A good deal of this new land is likely to be of poor quality and hardly fit for productive use. For this reason alone, pockets of hunger, poverty and failure will persist beneath the broad regional assumptions of the CDS that average incomes, dietary standards and food production will increase. Environmental resources will inevitably be lost since this new land will be taken from a mix of forest and woodlands, grasslands and wetlands, depending on regional land endowments and pressures. The impacts will undoubtedly be large but they are also most difficult to quantify due to enormous data variations and uncertainties.

Major impacts will include continued losses of living space and livelihood for forest-dwelling people and wildlife habitats. Biodiversity will be reduced and species driven to extinction. The many other productive values and ecological services of forests (and other biomes) will be diminished. Forest clearances will also produce greenhouse gas emissions, although total emissions related to agriculture could well be less than in the past due to the assumed slow down of cropland expansion. Also, to some extent these forest-related impacts will be counterbalanced by regrowth of forest, woodland or shrubs on abandoned farm lands. Large areas of the world's tropical and temperate forests, including so-called "primary" forest, are known to have grown from once-settled cropland (Wood, 1993), in at least one case to reach the status of a protected world-class forest Biosphere Reserve in only a century (Fairhead and Leach, 1995). On the other hand, much abandoned farm land in the developing world today becomed low yielding pasture lands, thus making deforestation irreversible in practice (Gallopin, 1995)

Water shortages and greater competition for water between agriculture and rapidly growing urban and industrial demands are other impacts of and threats to agricultural growth. According to some authorities (CGIAR, 1994), competition will be particularly serious through much of Africa and the Middle East, where recent high rates of irrigation expansion appear to be unsustainable, and Asia, where the continuation of recent trends would require an investment of US$ 500-1,000 billion by 2025 and could exhaust the irrigation potential by that date. These problems are discussed further in Section 4.6. To help resolve them much greater attention will have to be paid to unfamiliar techniques

such as small-scale water harvesting on dryland farms and to improved management of irrigation systems (CGIAR, 1994; Srivastava and Alderman 1993). With the latter, huge potentials exist all the way from the water source to the field and plant itself to reduce water losses and use water more effectively (Stanhill, 1986). These conservation techniques are rarely applied because farmers typically pay very little for irrigation supplies. For example, in California the price of water to most farmers has been about 10% of the supply cost (Gottlieb, 1991); during the late 1980s in China, when there were chronic droughts and urban water shortages, the equivalent figure was 5-20% of costs (Smil, 1993). More expensive water will increase farm costs but could also increase yields and production by making more water available through improved efficiency of use.

Pollution by fertilizers and pesticides are other serious environmental problems. Heavy fertilizer use in the intensively farmed lands of both the developed and developing regions is producing nitrate levels in drinking water which approach or exceed permitted levels, increasing the likelihood of government restrictions on fertilizer use (CGIAR, 1994). This is not yet a problem in much of the developing world where fertilizer use is very low, but could become so under the assumptions of the CDS that fertilizer use increases rapidly. However, these latter risks need to be balanced against the economic and environmental benefits of raising fertilizer usage. These include increased crop yields which reduce the need to farm new fragile lands and increased crop residues which make it more likely that surpluses over demand will be used as soil-protecting green manure and mulches (Pinstrup-Andersen, 1993). Heavy pesticide use in developing countries is causing serious harm to human populations (CGIAR, 1994) with declining benefits to farmers as pest populations become increasingly resistant and their predators are killed off.

Techniques are being developed to counter both these pollution problems -- including many biological approaches to nitrogen fertilization and pest control -- but they will require major investments for research, demonstration and implementation. Until these techniques are widely available at costs farmers can afford, these environmental impacts are likely to continue since their reduction will generally lead to lower food production and farm incomes.

4.8. Toxic Implications

In the Conventional Development Scenario, toxic emissions more than double by the year 2050 relative to current values. But the environmental burden associated with toxic emissions could be substantially greater. There are two main reasons for this. First, and most importantly, many toxic chemicals have long residence times in the environment leading to cumulative impacts. Second, toxic chemicals are increasingly sequestered in the growing stockpile of products yet to reach the end of their useful life. When these products are discarded into the environment, total toxic emissions will increase over and above those associated with manufacturing the products.

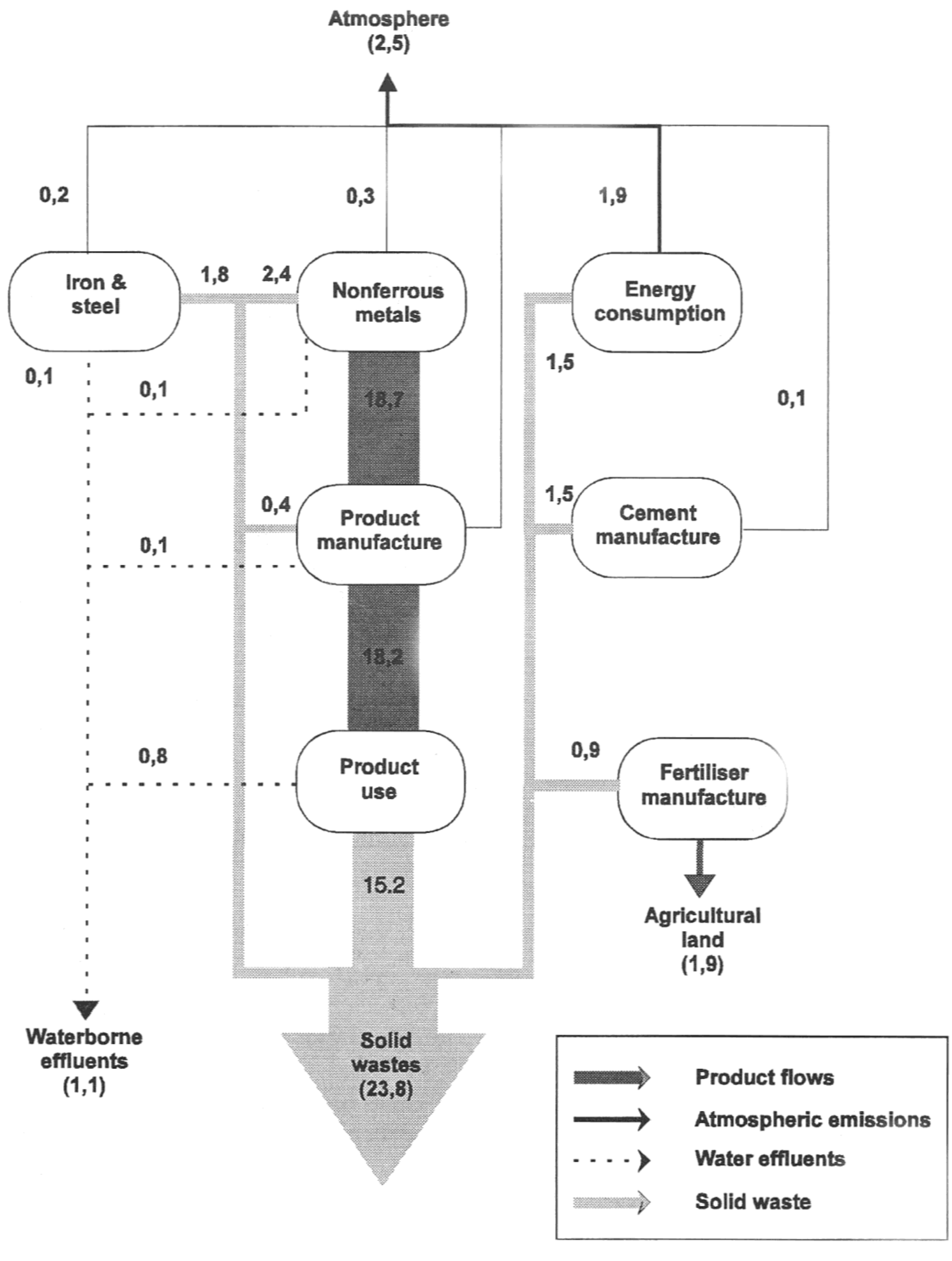
Both of these points can be illustrated by reference to the chlorofluorocarbons (CFCs). These chemicals are implicated both in the problem of ozone depletion and in greenhouse warming. Under the Montreal Protocol the production and consumption of five main types of CFCs will be phased out in many countries within a few years. However, due to long atmospheric residence times, these chemicals will continue to influence ozone levels in the upper atmosphere for several decades, and global temperature well into the 21st century. In addition, CFCs which are presently confined within products are likely to be emitted in the future. In many OECD countries, efforts to identify these products and prevent releases from unregulated disposal are made more complicated by the dispersion of CFC throughout the economy through a wide range of applications. In non-OECD regions, it is unlikely that an appropriate infrastructure for collection and disposal of CFC containing products will be deployed in time to prevent significant future emissions.

In fact there is a wide variety of chlorinated chemicals which are either resident in the environment as a result of past activities, dissipated in the stock of products, or still routinely discharged into the environment. A well-known example is the insecticide DDT, now banned in OECD countries, but still used in the developing world. DDE is a metabolite of DDT which is particularly toxic to humans and has long residence times in the environment. Polychlorinated biphenyls (PCBs) were once used as an insulating medium in electrical devices. Although PCBs are now banned in many western nations they are still widely dispersed in products throughout the world.

Another well-known example is dioxin, a compound which is formed in various processes, such as the incineration of chlorinated compounds. Chlorinated compounds in domestic refuse thus risk dioxin contamination from incineration. These considerations, and the complex environmental metabolism of chlorine, have led some observers to argue for a general phase-out of chlorine production (Thornton, 1991). As we shall see in Section 5.4, the implications of this suggestion are quite profound.

Some further difficulties of managing toxic chemicals can be illustrated with reference to toxic heavy metals such as cadmium, mercury or lead. Figure 30 shows the current flow of cadmium through the global economy (Jackson and MacGillivray, 1995b).

Figure 30 Principal anthropogenic flows of cadmium



The figure shows that cadmium flow is primarily in cadmium-containing products. In this form, the cadmium is probably at its least available, and therefore potentially at its least hazardous. However, cadmium is one of those substances which tends to accumulate within biological organisms and through the food chain. Even relatively small emissions of cadmium into the environment become increasingly important over time, and can lead to dangerous accumulation levels in the environment.

Of particular concern is the accumulation of cadmium in agricultural soils. The worst pollution episode from cadmium occurred in Japan in the 1950s as a result of contamination of the rice crop from cadmium-bearing industrial effluents. While this incident was a clear example of bad practice, cadmium is routinely dissipated into agricultural soils today. The two main sources are phosphate fertilisers and the application of sewage sludge to agricultural land. In phosphates, trace cadmium contamination is entirely geological in origin. Sludge contamination is the result of several stages of cadmium extraction, processing, distribution, and use before entering the sewage system. Continued application of cadmium to agricultural land leads to increasing levels of cadmium in the soil and the crop itself. While the data do not support precise projections, some agricultural land in heavily industrialised areas may become unsuitable for crop production long before 2050.

Moreover, the accumulation of cadmium in products -- an estimated 600,000 tonnes globally -- is a cause for concern. Though temporarily sequestered, the ultimate fate of these products is uncertain and thus present significant risks for the future.

These examples illustrate some of the dangers associated with increasing and widespread use of diverse industrial chemicals, and some of the complexity associated with their management. An important lesson from the past is how difficult it is to predict the behaviour of materials once they have been emitted into the environment. Complex processes of accumulation, cycling, and dissipation are accompanied by synergistic reactions between different chemicals which pose additional risks. For example, the acidification of water supplies increases the availability of toxic metals in the aqueous environment. Rising sea water levels from global warming might also have toxic impacts by increasing the mobility of toxics dissipated in soils.

This kind of "toxic shock" scenario might be explored as a special case (Stigliani et al., 1984), though the more likely scenario is the gradual dissipation of toxic materials into the environment, and their increasing accumulation in water supplies, soils and agricultural products. It is against this trend that precautionary measures must operate in the transition to sustainable development.

4.9. Social and Political Aspects

The defining theme of the conventional development scenario is the advance of global markets and the progressive homogenization of culture. The process of

incorporation and transformation of traditional cultures by the inexorable expansion of capitalist markets is centuries old. So has been the resistance, often futile, to such socio-economic transformations, though remnants of folk ways survived in the interstices of the new market driven societies, while entire nations preserved a unique national style, blending traditional behaviors and values into the modernization process. The combined effects of the explosion of mass media, the mobility of populations, and the far-flung penetrations of global markets has ushered in a new era in the long process of culture homogenization, and given it unprecedented reach and force.

In the abstract, the growth of a globally-shared culture might be thought to be a force for international unification and understanding, eroding local parochialism and biases. In fact, the implications are complex. The mass appeal of chauvinistic religious, ethnic, and regional movements may in part be a reaction to the perceived threat of foreign attitudes and behaviors which are incompatible with the maintenance of traditional values. Resentments and fears are inflamed by the often violent, sexually explicit and materialistic images of the advancing dominant culture, and the sense with many that a world they understand is being transformed and dominated by a new colonialism. While apparently its opposite, the fundamentalist backlash is closely coupled to the globalizaton trend.

Moreover, those skeptical about claims for the progressive effects of global markets and culture can point to social crises in the heart of advanced countries like the United States -- escalating crime rates, unstable families, a growing urban underclass, affluent but anomic youth. It is also worth noting that for many the combination of the exposure to the allures of the global emporium and the absence of the incomes to live that way is a recipe for indignation. The maintenance and, if present patterns continue, even deepening social and distributional inequities both between and within societies, in the context of globalization processes and media saturation, can undermine social cohesion and sustainability. With its potential to reduce cultural diversity and sources of cultural and scientific richness, and to stimulate social reaction, the globalization process is both powerful and deeply problematic.

The grave environmental and resource pressure of the conventional development path, in the context of continued inequity between and within nations, could compromise social stability and international cohesion. As we have seen, while income growth rates for the poorer regions are higher than average, the disparity between rich and poor grows in *absolute* terms. Furthermore, in the absence of policies to reduce widening income disparities within countries, the absolute number of people living in conditions of dire poverty could increase if the assumed growth in income is counterbalanced by growth in population.

In our bifurcated world of rich and poor countries, poor countries are under heavy pressure to export commodities in order to meet the basic needs of their people, to purchase vital imports, and to pay international debts. Often, this means exploiting natural land and

mineral resources with little regard for the long term costs in resource depletion and environmental deterioration. If developing countries are to make the transition to globally sustainable practices, affluent countries will need to transfer appropriate technologies, forgive debts, and promote development that meets needs and aspirations while preserving environments. This requires greater equity among nations.

The international security system would be stressed in a world where deepening environmental scarcities can contribute to conflict (Homer-Dixon, 1994). Tensions would be particularly acute if environmental degradation in various areas stimulates additional migration to richer areas. Incipient breakdowns in national and international stability could in turn provide conditions for authoritarianism, for the flaring of regional, ethnic, and religious conflict, and the suppression of democratic institutions.

5. Dimensions of the Transition

We have argued that the conventional development pathway is probably neither self-consistent nor feasible. If conventional development presents unsatisfactory risks, what proactive initiatives are warranted to make a transition from a conventional development scenario to a "success" scenario that would reduce the likelihood of unfavorable surprises and provide a more resilient pathway to sustainability? Here we restrict ourselves to general comments about aspects of the transition.

5.1. Energy

In broad terms, the challenge for energy policy posed by the conventional development scenario exercise is clear: greater efficiency in the production, conversion and consumption of energy, and greater use of renewable resources. Strategies need to be customized at global, regional, national and local levels. A wide range of policy *instruments* is available for achieving strategic targets, with the appropriate mix varying to conform with local institutional constraints and predilections.

Environmental costs can be reflected in the price of energy as a means for guiding consumption levels and fuel choices. Minimum efficiency standards can be set for appliances, lighting, motors and other end-uses, including automobiles. The regulatory process can direct electric utilities toward integrated, least-cost programs that include an emphasis on reducing demand on the customer's side of the meter. Direct subsidies can catalyze the development of desirable technologies -- and unwarranted subsidies for conventional fuels can be eliminated. Educational and promotional campaigns can induce individuals and enterprises to practice better energy management. Government purchasing programs can provide initial markets for emerging technologies. Research and development agendas can nurture renewable resource development. International trade agreements can ensure that sound national standards and practices are protected.

5.2. Water

The so-called *watershed perspective* provides an integrated framework that transcends the conventional water sector policy focus on hydrology, water engineering and flood control by conceptualizing the role of water in the complex chemical, physical and biological processes and interactions that comprise human and natural systems (Shabman, 1993). This approach places considerations of land-use, water quality, biotic preservation and the maintenance and restoration of ecosystems alongside the engineering of water systems to service economic and development requirements.

The delineation of an appropriate mix of water applications -- withdrawals, in-stream activities, waste assimilation, preservation and restoration of lakes, rivers, wetlands and estuaries -- will require a valuation process for addressing these varied uses in an integrated framework. Demand-side measures to improve the efficiency of water use at lower costs than increasing supply need to be included in such integrated and least-cost development strategies. In comparing options, both monetary costs and non-

monetary environmental and social costs which are *external* to the market must be considered.

There is growing international concern that water scarcity and water degradation threaten the prospects for a sustainable future (ICWE, 1992). In most countries, the transition to sustainable water management will require overcoming the current fragmentation of institutional responsibilities where numerous agencies plan and make policy that effect water withdrawals, power generation, land use in watersheds, macroeconomic policies that influence the water sector, and environmental protection. New institutions will need new water professionals who can integrate engineering, ecological and social aspects of water development. Finally, international processes are needed for the management of international rivers, lakes and seas in a manner that reduces the threat of conflict and environmental degradation of common resources.

5.3. Agriculture and Land

The main elements of a strategy to increase food production greatly and do it sustainably are clear: do more to support the world's farmers -- especially the resource-poor majority -- with better research, information, infrastructures and incentives, within a broadly favorable and stable macro-economic environment.

The root problem is that poor farmers who lack access to productive resources are more likely to produce little and degrade land than the better endowed (Blaikie and Brookfield, 1987; Pinstrup-Andersen, 1993; English, 1993). They will produce more if they are paid enough by markets they can reach (Sen; 1994). They are likely to produce more in a sustainable manner if they have secure rights to the land they manage. They might produce more, sustainably, by increasing external technical inputs such as artificial fertilizers to boost yields or some degree of mechanization to alleviate labor shortages, if they can afford or get access to these. Or they might apply innumerable local, high-skill methods which can in many cases maintain soil qualities and double or triple crop yields with little or no use of external inputs (Pretty, 1994). Where population densities are low, as in much of Africa, both of these broad classes of developments might occur spontaneously due to population growth, which drives technical innovation and adoption as a result of evolving market forces (Boserup, 1965, 1981). This process of "autonomous intensification" was a main engine of agricultural development in Europe and Asia (Lele and Stone, 1989). However, in many places these processes will no longer be sufficient to ensure sustainable agricultural and income growth and must be backed by a large array of public policies at every institutional level.

At the international level, global trade barriers and prices have cut the value of many crops which are critical to the economies of developing countries and their farmers. Radical reforms of global food pricing and trading policies might be required to enable the large production increases which are needed. Crucially, these reforms must be based on a longer-term perspective than normally used by the market. One of the most crucial

findings of our analysis (see Figure 14) is that even with large increases in crop areas and yields, some developing regions will have to turn increasingly to food imports from the industrial world. Production in the latter regions must be stepped up to meet these needs during a period when domestic demand is expected to stagnate or decline.

At the national level, civil strife, unstable governments, rigid state institutions and policies, weak agricultural support services, overvalued exchange rates, heavy taxes on agricultural exports and controls which reduce farm prices to a fraction of world market values, have combined with widespread neglect of rural infrastructures to undermine the entire agricultural enterprise - reducing farm profitability, increasing risks, preventing significant productivity gains and contributing to the persistence of rural poverty. In Africa particularly, poor roads, weak market structures and lack of credit facilities have greatly increased the costs of farm inputs such as fertilizer and reduced farm output prices, severely blunting incentives to switch from subsistence to market production and from extensive to intensive farming (Cleaver, 1993). At the same time, inequitable land ownership and tenure systems have discouraged sustainable land use practices.

These policy failures will not be corrected overnight, although most governments and donor agencies know that they require urgent and sustained attention. In the meantime, though, there is a large and potentially most rewarding agenda for scientific research, education and dissemination to farmers of a host of more productive and environmentally benign agricultural technologies. Establishing their widespread use on the world's farms amounts to launching a new "doubly green" revolution which is more productive than the first green revolution and much greener in terms of conserving natural resources and the environment (CGIAR, 1994).

Most of these "new" techniques rely on improved information and skills rather than resource-intensive, material inputs. They include the selection and creation of improved animal and plant varieties; biologically-based pest control strategies; biological methods of increasing nutrient uptake by plants; more diverse and complex crop rotations; better spacing of crop plants; minimum tillage and green manuring systems to increase yields and erosion-preventing ground cover; agroforestry systems which can simultaneously increase useful production, protect soils and enrich them with additional nutrients; the "fine-tuning" of fertilizer and water applications in space and time to maximize their effective use; and cheap soil testing methods to allow more precise correction of soil nutrient deficiencies and reduce unnecessary over-fertilization (Serageldin, 1993; Antholt, 1994)

Research also has to start from the real needs, constraints and opportunities of farm households in different environments and build up from there, rather than starting from the top down in research laboratories. The fruits of research must also be delivered to the people who need them: good information systems, targeted to local audiences and their needs, are vital tools for narrowing the huge gaps in yields and good husbandry practice between research stations, "best" farmers and the average farmer. These

requirements call for some fundamental changes to the structures and objectives both of international and national agricultural research centers and national agricultural advice and extension services.

Some have concluded that if the research goals outlined above are pursued vigorously, with substantially increased investments, future world populations can be adequately fed, malnourishment eliminated, environmental degradation prevented and natural resources conserved (CGIAR, 1994). A more sober conclusion might be that, while the potential for reaching this benign state of affairs is indeed enormous, the path towards it will certainly not be smooth. In a future of very rapid change and large uncertainties, we can expect both the Malthusian pessimists and the technical optimists to be right in different places and at different times, while we have to remain ignorant about the total outcome.

5.4. Materials

As we have discussed, the material basis of the conventional development scenario is very diverse. There are environmental risks associated with a wide range of materials flowing through industrial economies. Concern has focused on those materials which are "persistent, toxic and liable to bioaccumulate", the properties which maximise the risk of human exposure and environmental damage. However, these properties do not exhaust the possibilities for long-term environmental risk. The emission of carbon to the atmosphere, or nutrients to the aqueous environment, illustrate that even non-toxic substances can pose environmental threats, if released in sufficient quantity.

For these reasons, sustainability requires a significant de-materialisation of economic activities. There is an argument that this process has begun already in certain developed countries.[22] In fact, the Conventional Development Scenario allows for some gradual de-materialisation with respect to materials such as iron, steel and concrete. But it is important to be wary of excessive optimism for such "natural" de-materialisation. First, current evidence for such a process is drawn from developed economies, which are increasingly importing finished products from industrialising economies elsewhere in the world. Second, the range of materials over which there is evidence of de-materialisation is rather small. Finally, dematerialisation is generally expressed as a decreasing trend in material intensity per unit of economic output, so that the aggregate material burden will eventually rise unless material intensity falls faster than the rise in GDP.

In the long-term, these considerations may require the re-examination of assumptions about the nature and feasibility of continued economic growth. In the near term, efforts to ensure sustainability must place a strong emphasis on reducing the "material intensity per unit of service (MIPS)" across the broad range of consumption and

[22] Bernardini and Galli (1993) have argued that the relationship between material intensity and economic growth is described by bell-shaped environmental Kuznets curves, in which material intensity first peaks then declines as GDP increases.

production activities (Schmidt-Bleek, 1993; Jackson, 1996). Naturally, policy needs to focus first on priority hazards such as those presented by toxic heavy metals or the use of chlorinated organic compounds. Even these specific cases, however, pose significant challenges. The cases of cadmium and chlorine illustrate some of the complexity associated with the anthropogenic pathways of hazardous material (see Section 4.8).

Chlorine has multiple uses such as water purification, the paper and pulp industry, and the manufacture of dyes, resins, plastics, solvents and wide variety of other industrial chemicals. While in some applications there are suitable substitutes for chlorine, substantial reductions would have profound implications in many economic sectors. The widespread use of PVC for example binds the conventional development paradigm to complex and potentially hazardous chlorine chemistry. In addition, a transition to a de-chlorinated society would force the re-examination of sodium hydroxide use, a co-product of chlorine in the chloralkali industry. Alternative industrial processes for the manufacture of this product would need to be explored, or from a de-materialisation perspective, policies to reduce the reliance of industrial economies on sodium hydroxide chemistry to be considered.

The transition to sustainable development will require a probing inquiry into the chemical, physical, economic and social aspects of our reliance on materials, with the aim of a significant de-materialisation of human activities. There are weighty economic implications of such a transition. For example, there will be a need to re-negotiate the basis of profitability in the industrial economy, which traditionally has been provided by the sale of material goods. If de-materialisation is to be successful, producers of material goods will be faced with reduced throughput of material goods. Revenues will need to be based instead in the concept of providing services,[23] offering in principle the prospect of re-defining the relationship between material goods and human activity, and significantly reducing our material impact on the environment.

5.5. Beyond Conventional Development

While the critique of the conventional development scenario cannot in itself provide a detailed blueprint for a transition to sustainability, it does suggest the contours for new directions. Policies and instruments for change must be suitably tailored to specific conditions and constraints operating at all levels, and adjusted as new information becomes available. Nevertheless, the lessons emerging from an increased understanding of what conventional development entails do begin to outline a strategic agenda for sustainability.

Ultimately, the transition must transcend mere changes in sectoral policies. The deep drivers of unsustainability must be better understood, and new visions and development paradigms for the transition to sustainability formulated. Cutting across specific actions is the larger question of the kind of society we want, the constellation of

[23] Discussed in detail in, e.g., Stahel and Jackson (1993) and Jackson (1996).

values, ways of life, consumption patterns and institutional arrangements for fostering sustainable human development.

In the course of progressing an integrated sustainability perspective, fundamental principles will need to be considered anew. Related to population issues is the need to:

- adopt a more rational approach to settlement expansion,
- balance land uses and preserve ecosystems,
- increase educational and employment opportunities for women,
- provide basic health and welfare services,
- eliminate poverty and enhance economic security.

On the economic front, it is necessary to:

- reframe tax and subsidy structures to discourage wasteful use of resources and encourage efficient, clean and resource-saving technologies,
- implement incentives which restrain the growth imperative lying at the heart of competitive markets systems,
- decouple development goals from growth in economic scale,
- operationalize the polluter pays principle by internalizing non-monetarized environmental costs through a mix of taxes, tradable permits and regulations,
- restructure standard economic accounts by deducting the loss of natural capital, defensive expenditures for environmental protection and other “bads”.

Social and political institutions need to be encouraged to:

- establish appropriate and effective governance structures, downwardly delegating decision-making where possible but ensuring the compatibility of local actions with regional and global sustainability goals,
- include the maintenance of resource and environmental systems as key element in international security arrangements,
- foster international and intranational equity and human rights to promote social cohesion and international solidarity as preconditions for meeting the sustainability challenge,
- promote the development, deployment and international transfer of efficient and clean technologies,
- reflect an emergent ethic that places greater weight on lifestyles rich in culture and intellectual challenge, community propinquity and international diversity, spiritual fulfillment and experience of nature.

It would be highly imprudent to assume that the internal socio-economic and bio-physical tensions of the conventional development world do not pose serious risks to the health of socio-ecological systems. The burning issue is whether the transition away from the conventional development path can be made in a way that, at a minimum, avoids

significant disruption and destabilization, and, ideally, is seized as an opportunity for social renewal.

But a successful global process for envisioning and realizing sustainability is far from assured. What alternative visions of development can help guide humanity in a new and uncertain epoch? How will there be engendered sufficient popular awareness and political will to mount a coherent strategy and effective policies for a positive transition? How can the emergence of institutions for balancing individual, short-term interest with collective, long-term sustainability values be assured?

In light of the disquieting trends shaping our world, these questions invite a major program of research and education, and a long process of social change. The sustainability transition commands the continued engagement of voices representing a wide range of insights and aspirations. Three key issues will remain central to sustainability concerns: the protection of natural resources and the environment; achieving legitimate development aspirations; and passing on satisfactory conditions to future generations. Only as these are adequately addressed can we see our way forward to a better social and environmental compact for the next century.

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